

Microservices Architecture

(MSA for Telco)

2023년 7월
안종석
james@jslab.kr

Microservices Architecture

(MSA for Telco)

I. 'MSA와 5G 네트워크'	3
II. '가상화 (Virtualization) 인프라'	94
III. '클라우드 서비스'	166
IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'	238
V. '관리/보안'	290
❖ 실습 자료 (별도)	

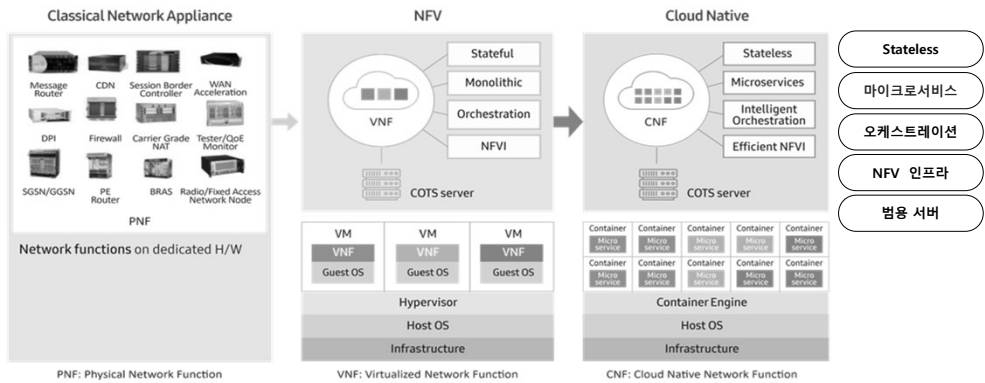
I. 'MSA와 5G 네트워크'

- MSA(Microservices Architecture) 개요
- 통신 시장의 클라우드 서비스 기술 변화
- 5G 네트워크 서비스의 클라우드화
- Cloud Native Transformation

3

I. 'MSA와 5G 네트워크'

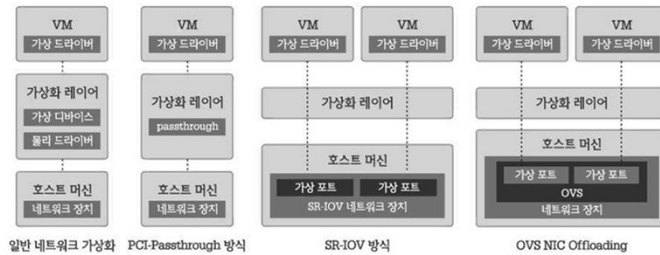
- ❖ PNF(Physical Network Function) *하드웨어 어플라이언스 기반
- ❖ VNF(Virtualized Network Function) *가상머신 VM(Virtual Machine) 기반
- ❖ CNF(Cloud-Native Network Function) *클라우드 네이티브는 컨테이너/VM수용



4

I. 'MSA와 5G 네트워크'

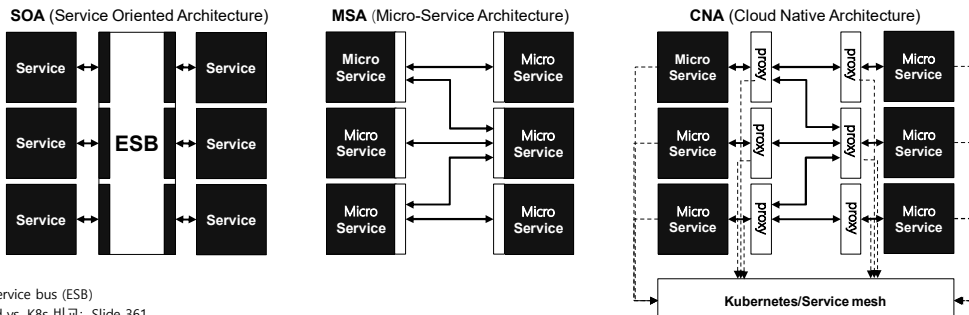
- ❖ VNF (Virtual Network Function)의 마이크로 서비스화
- ❖ VNF의 MSA화를 통한 각 모듈의 간소화 및 각 모듈 간의 SBA에 기반한 통신
- ❖ VNF의 컨테이너화 / 마이크로 서비스화
 - Kubernetes 도입에 따른 운영 환경 변화
 - Kubernetes Networking: 물리 장비와 동일한 네트워크 성능을 보장 해야 하며, 이를 위해서 SR-IOV, OVS-DPDK와 같은 가속 기술 사용이 필요



Source: SDN/NFV 기반 5G 통신망 인프라의 진화, 정보화진흥원, SKT 신상호 매니저

I. 'MSA와 5G 네트워크'

- ❖ Service Oriented Architecture (SOA)
- ❖ Microservice architectures (MSA)
- ❖ Cloud Native Architecture (CNA) Microservice Based Architecture

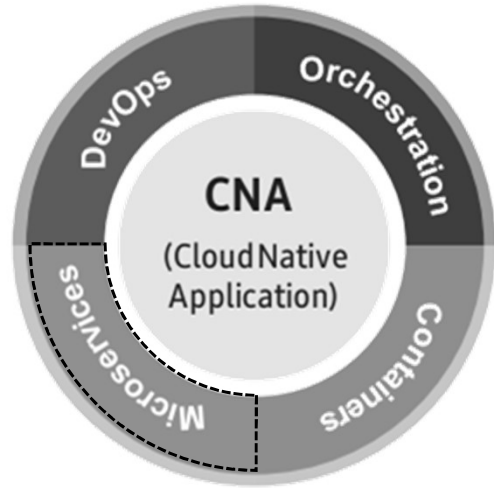


enterprise service bus (ESB)
Spring Cloud vs. K8s 비교: Slide 361

I. 'MSA와 5G 네트워크'

❖ Cloud Native 5G

- DevOps
- Microservices
- Containers
- Orchestration



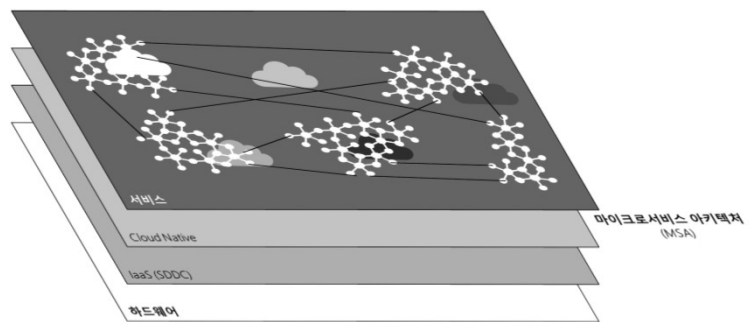
** Check 'KubeVirt'
Source: Cloud-Native Application
Source: <https://moniem-tech.com/2021/06/24/what-does-5g-cloud-native-means/>



I. 'MSA와 5G 네트워크'

❖ 계층화 인프라

- 인프라의 계층별 추상화 (서비스에 집중)
- 계층간 격리와 정책 기반 서비스 노출
- 성능 개선 (계층 Offload)
- 연결 호환성



SDDC (Software Defined Datacenter), IaaS (Infrastructure-as-a-Service), MSA (Microservices Architecture)



I. 'MSA와 5G 네트워크'

❖ Transitioning From 5G To 6G

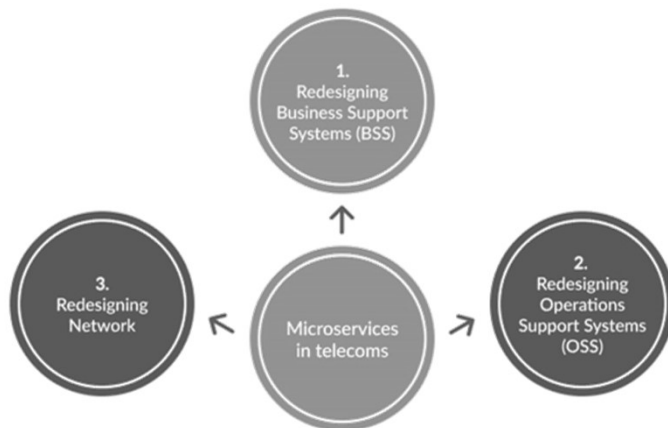
Past 10 years (Central Cloud)	Next 10 years (Decentralization driven by Distributed cloud)
Applications: Monolithic	Microservices
Application Migration: On-Prem to Central Cloud	Applications distributed across multi-cloud or micro-DCs
Applications: Non-real time	ultra-low latency Applications
Centralized Hyperconverged Infrastructure (HCI)	Decentralized Converged Infrastructure driven by integrated connectivity, compute and storage
Cloud: Siloed (Migration is not seamless)	Multi-Cloud (Seamless Applications migration)
Centralized AI/ML algorithms for training and inference	Distributed, federated , coordinated real time explainable systems (for decentralized training and inference)
Traditional Software Release mgmt.,	Automated Software Release Mgmt with DevOps and CI/CD
VM Based (little of Container)	Container based, Serverless
Fragmented orchestration systems & Siloed Clouds	Kubernetes for multi-cloud (Telco, Enterprise and public cloud)
Event, Static Management driven	Data driven, Autonomic Services Management

NOVEMBER 10TH, 2022 - BY: PAUL MCLELLAN
 Source: <https://semiengineering.com/edps-transitioning-from-5g-to-6g/>

I. 'MSA와 5G 네트워크'

❖ 텔코의 마이크로서비스: How to embrace microservices in telecom (infosys)

- Redesigning BSS
- Redesigning OSS
- Redesigning Network

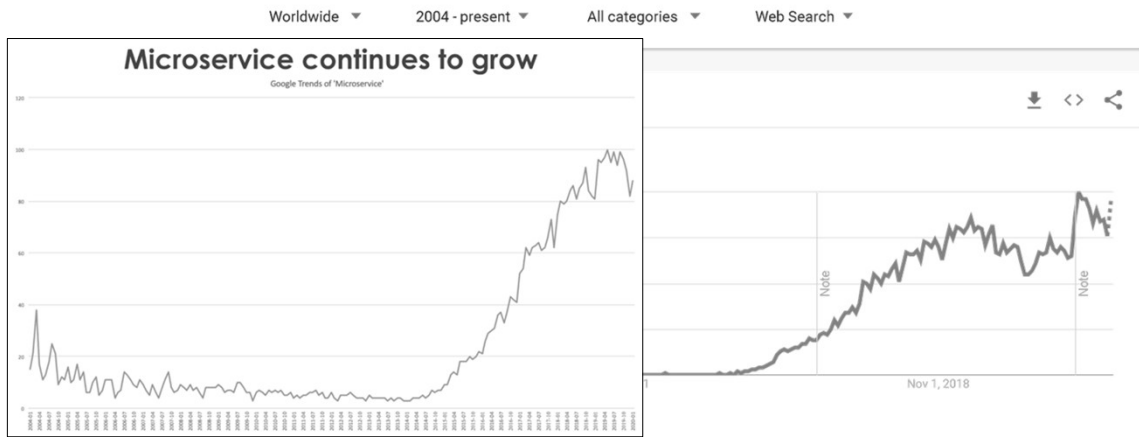


Source: Infosys

Source: <https://www.n-ix.com/implement-microservices-in-telecoms-effectively/>

I. 'MSA와 5G 네트워크'

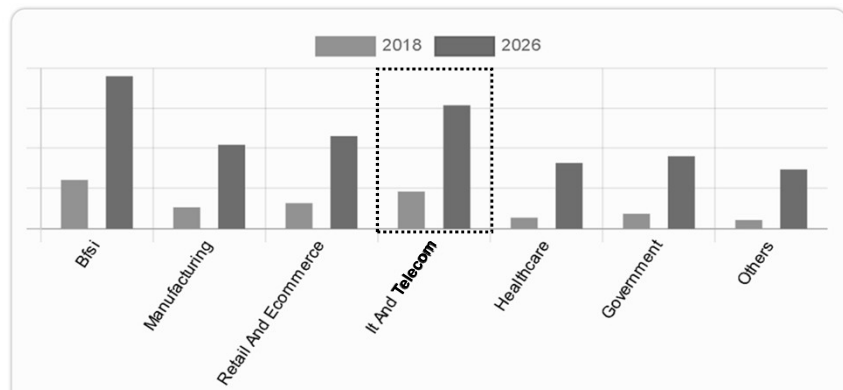
❖ 구글 트렌드의 마이크로서비스: Interest in microservices has grown exponentially, as demonstrated by search trends on Google. (2022)



I. 'MSA와 5G 네트워크'

❖ 시장별 마이크로서비스: Microservices Architecture Market by Industry Vertical (2020)

- According to a report by Allied Market Research, the global microservices architecture market size estimates to reach \$8073 million by 2026, registering a CAGR of 18.6% from 2019 to 2026.



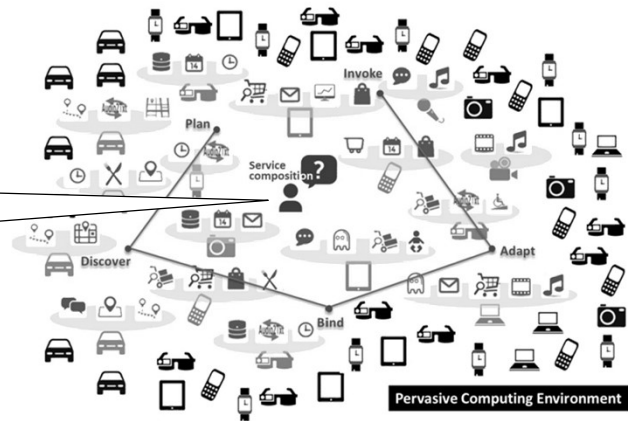
Banking, financial services and insurance (BFSI)

Source: <https://www.alliedmarketresearch.com/microservices-architecture-market#:~:text=The%20global%20microservices%20architecture%20market,18.6%25%20from%202019%20to%202026>

I. 'MSA와 5G 네트워크'

- ❖ 모바일을 위한 마이크로서비스 (예): Motivating scenario 'a smart public space system'.
 - A user issues a complex service request to a pervasive computing environment. Connected entities offer their hardware/software capabilities and local data as microservices.

사용자는 복잡한 서비스 요구를 퍼베이시브 컴퓨팅 환경에 요청하며, 컨텍스트개체들은 하드웨어/소프트웨어 능력과 데이터를 마이크로서비스로서 제공

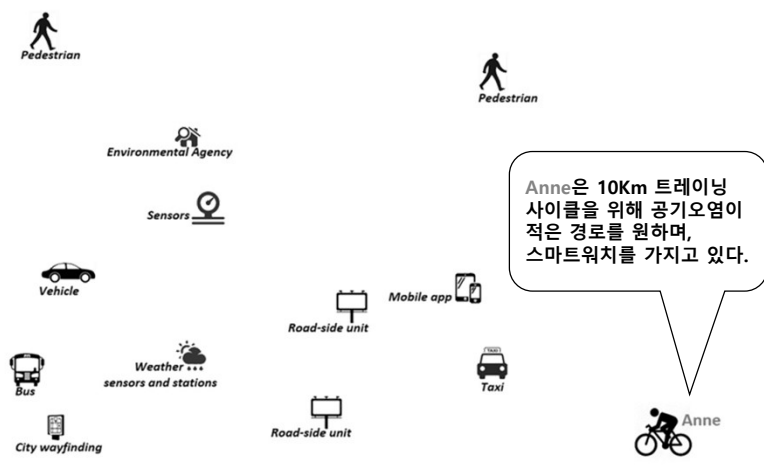


Pervasive (퍼지는, 널리 미치는, 스며드는)
Source: Chen, Nanxi. Mobile Microservices (p. 6). CRC Press. Kindle Edition.



I. 'MSA와 5G 네트워크'

- ❖ 모바일을 위한 마이크로서비스 (예): A composite service to satisfy a complex task

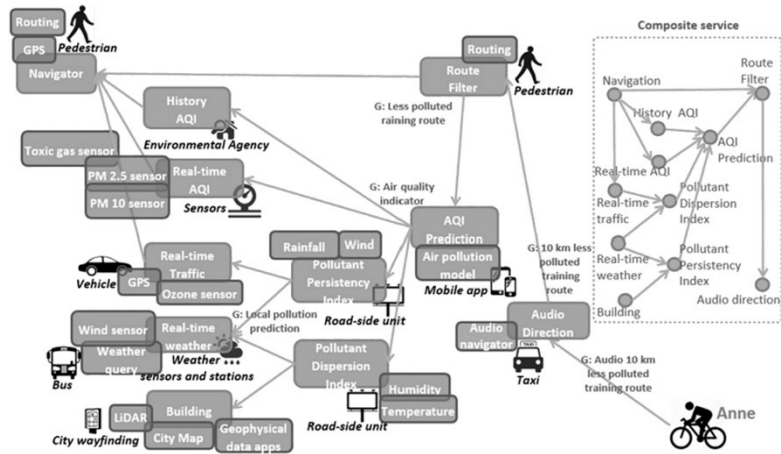


Source: Chen, Nanxi. Mobile Microservices (p. 7). CRC Press. Kindle Edition.



I. 'MSA와 5G 네트워크'

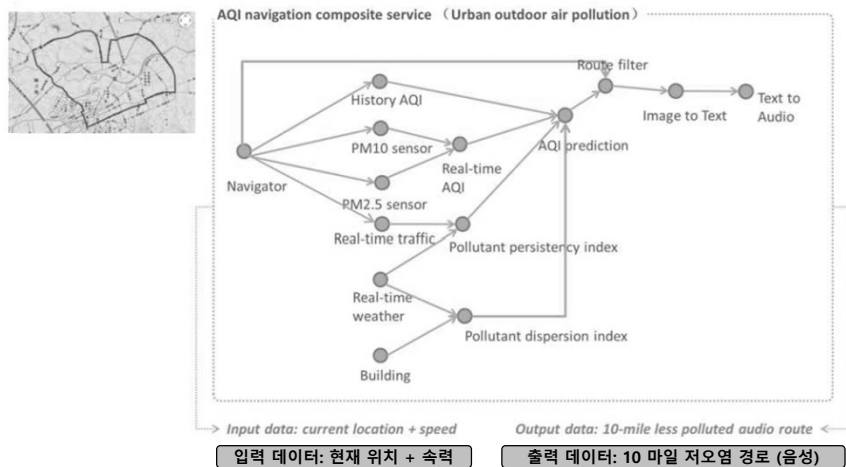
❖ 모바일을 위한 마이크로서비스 (예): A composite service to satisfy a complex task



Air Quality Index (AQI)
Source: Chen, Nanxi. Mobile Microservices (p. 7). CRC Press. Kindle Edition.

I. 'MSA와 5G 네트워크'

❖ 모바일을 위한 마이크로서비스 (예): Input and output data of the composite service

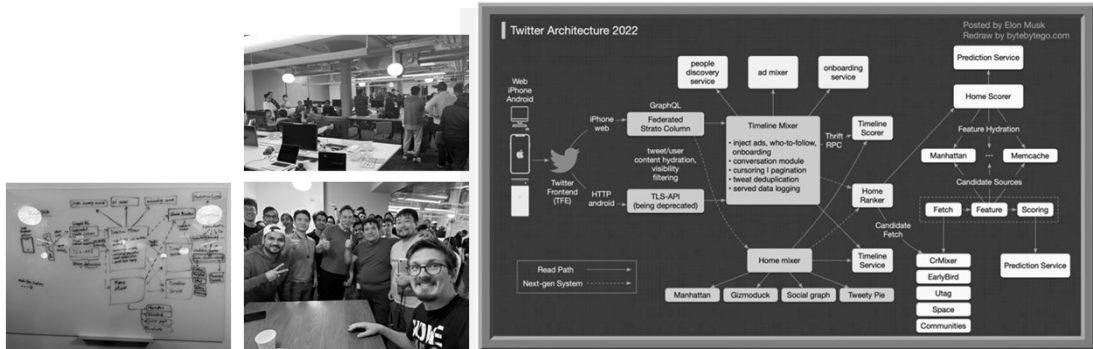


Source: Chen, Nanxi. Mobile Microservices (p. 8). CRC Press. Kindle Edition.

I. 'MSA와 5G 네트워크'

❖ 일론머스크가 직원들과 코드 리뷰 후 공개한 트위터 아키텍처 (2022)

1. 프론트 요청은 REST API(안드로이드용)를 GraphQL(아이폰/웹용)로 이전 중
2. 백엔드 타임라인 및 홈 믹서는 다양한 마이크로 서비스를 참조하여 콘텐츠 생성
3. 이를 위해 다양한 스코어링, 랭킹 서비스 사용



Source: https://twitter.com/elonmusk/status/1593899029531803649?s=46&t=faUozluMU3hLOC5z73PjRg&fbclid=IwAR10PjTyeNQ-9GlgQPSH_sx7is49mmuAE2BB3ZCzcnIUaWqXb7UFMjU

I. 'MSA와 5G 네트워크'

❖ 마이크로서비스 아키텍처 MSA (TTA의 정의)

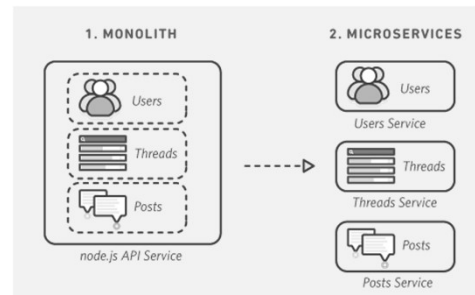
- MSA 대규모 소프트웨어 개발에 적용하기 위한 것으로 단독으로 실행 가능하고 독립적으로 배치될 수 있는 작은 단위(모듈)로 기능을 분해하여 서비스 하는 아키텍처.
- 작은 단위로 기능을 분할할 때 수직 방향의 기능별로 절단
- 절단된 독립적인 작은 모듈인 마이크로서비스는 공유나 프로세스 간 통신이 없이도 독립적으로 실행되며 운영 관리
- 마이크로서비스 간 연결은 응용 프로그래밍 인터페이스(API: Application Programming Service)를 이용
- 마이크로서비스는 표현이나 데이터 관리 등에 있어 기능적으로 완전
- 마이크로서비스 아키텍처 사용으로 개발자들이 클라우드 망을 통해 공유하고 협업하여 자유롭게 소프트웨어를 개발
- 개발 및 유지보수에 드는 시간과 비용이 절감
- 기존 모놀리식(monolithic) 방식과 반대되며, 서비스 지향 아키텍처(SOA: Service-Oriented Architecture) 방식보다 더 세분화

Source: http://www.tta.or.kr/data/weeklyNoticeView.jsp?pk_num=5193 - depleted

I. 'MSA와 5G 네트워크'

❖ 마이크로서비스 (아마존 AWS의 MSA 정의)

- 마이크로서비스는 소프트웨어가 잘 정의된 API를 통해 통신하는 소규모의 독립적인 서비스로 구성되어 있는 경우의 소프트웨어 개발을 위한 아키텍처 및 조직적 접근 방식입니다. 이러한 서비스는 독립적인 소규모 팀에서 보유합니다.
- 마이크로서비스 아키텍처는 애플리케이션의 확장을 용이하게 하고 개발 속도를 앞당겨 혁신을 실현하고 새로운 기능의 출시 시간을 단축할 수 있게 해 줍니다.



Source: <https://aws.amazon.com/ko/microservices/>



I. 'MSA와 5G 네트워크'

❖ 마이크로서비스 (마이크로소프트 Azure의 MSA 정의)

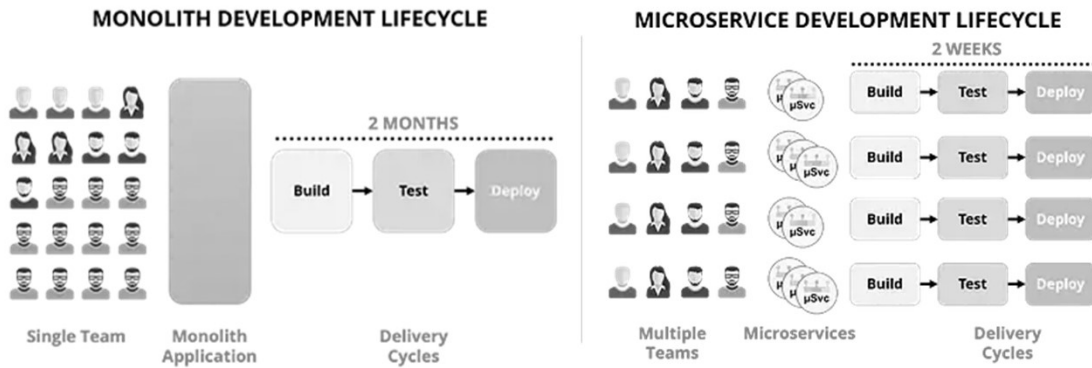
- 마이크로 서비스는 작고, 독립적이며, 느슨하게 결합되어 있습니다. 하나의 소규모 개발자 팀이 작성하고 유지 관리할 수 있습니다.
- 각 서비스는 작은 개발 팀이 관리할 수 있는 개별 코드베이스입니다.
- 서비스를 독립적으로 배포할 수 있습니다. 팀이 전체 애플리케이션을 다시 빌드한 후 재배포하지 않고도 기존 서비스를 업데이트할 수 있습니다.
- 서비스가 해당 데이터 또는 외부 상태를 유지해야 합니다. 이는 별도의 데이터 레이어가 데이터 지속성을 처리하는 기존 모델과의 차이점입니다.
- 서비스가 잘 정의된 API를 사용하여 서로 통신합니다. 각 서비스의 내부 구현 세부 정보는 다른 서비스에서 숨겨집니다.
- 다중저장소 프로그래밍을 지원합니다. 예를 들어 서비스가 동일한 기술 스택, 라이브러리 또는 프레임워크를 공유할 필요가 없습니다.

Loosely Coupled (느슨한 결합) Reference 'OpenStack' : Slide 357, Slide 358
Source: <https://docs.microsoft.com/ko-kr/azure/architecture/guide/architecture-styles/microservices>



I. 'MSA와 5G 네트워크'

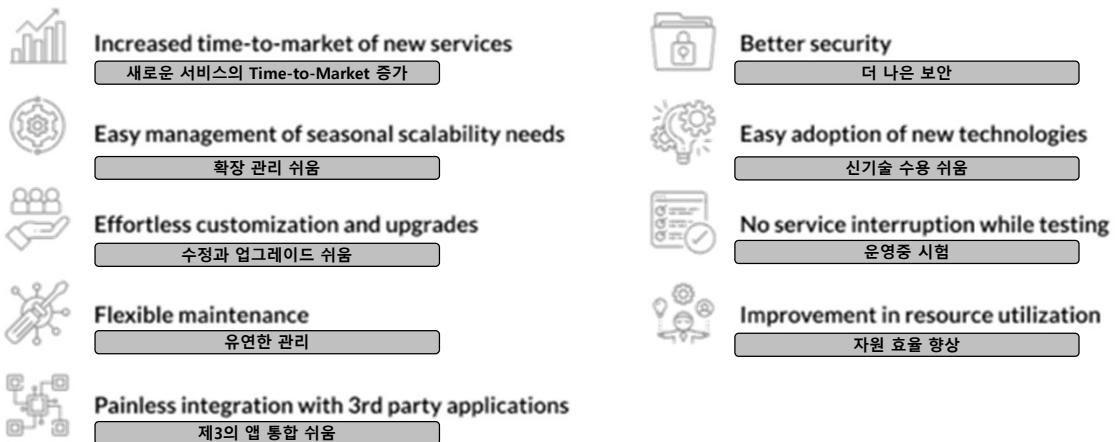
❖ Less dependencies. Business functions are built in parallel, reducing complexity.



Source: <https://beesion.com/development-process/>

I. 'MSA와 5G 네트워크'

❖ Benefits of microservices architecture in telecoms (N-iX)



Source: <https://www.n-ix.com/implement-microservices-in-telecoms-effectively/>

I. 'MSA와 5G 네트워크'

❖ Key 5G Features in 3GPP Releases 15, 16, and 17



SBA: Service-Based Architecture
 RAN: Radio Access Network
 MTC: Machine Type Communications
 IoT: Internet of Things
 API: Applications Programming Interface
 MEC: Multi-Access Edge Compute
 NSA: Non-Standalone
 SA: Standalone
 V2X: Vehicle to Everything

WLAN: Wireless Local Area Network
 NR: New Radio
 NR-U: New Radio Unlicensed
 HARQ: Hybrid Automatic Repeat Request
 IIoT: Industrial Internet of Things
 URLLC: Ultra-Reliable Low-Latency Communications
 NPN: Non-Public Networks
 LAN: Local Area Networks
 MIMO: Multiple Input Multiple Output

Source: <https://www.3gpp.org/specifications-technologies/3gpp-work-plan>
 Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

5G Phase 1
 Release 15
 (2017-2019)

5G System and Packet Core:

- SBA-based architecture
- Massive MTC and IoT
- API Exposure to third party
- Cloud friendly (SBI)
- Network Slice as a Service
- MEC

RAN:

- New Radio specification
- NR NSA (option 3x)
- NR SA (option 2/4/5/7)
- Wide bandwidth (~400 MHz)
- Wide Freq Range (up to 28GHz)

Industry verticals:

- V2X Phase 2
- Mission Critical Interworking
- WLAN and unlicensed spectrum

5G Phase 2
 Release 16
 (2018-2020)

5G System and Packet Core:

- Anchored NR-U
- Standalone NR-U
- Integrated Access and Backhaul (IAB)
- CAPIF enhanced

RAN:

- NR Positioning
- NR Coverage
- UE power saving techniques
- HARQ enhancement
- Enhanced Scheduling
- Coordinated multi-point (CoMP)

Industry verticals:

- Time-Sensitive Networks
- C-V2X enhancement
- IIoT and URLLC support
- NPN support

Phase 3
 Release 17
 (2020-2022 expected)

5G System and Packet Core:

- 5G LAN type services
- 5G Wireline and Wireless Convergence
- Edge Computing in 5G
- IAB enhancement
- Network Slicing - phase 2
- Multi-SIM
- Access Traffic Steering

RAN:

- NR Coverage enhancement
- NR Positioning enhancement
- NR Quality of Experience
- NR MIMO
- RAN Slicing
- Multi-Radio DCCA enhanced

Industry verticals:

- IIoT and URLLC enhanced
- NB-IoT and LTE-MTC enhancement
- Unmanned Aerial Systems
- Satellite components
- Enhanced V2X Services
- NPN enhanced

산업 응용 분야 확장

I. 'MSA와 5G 네트워크'

❖ Key 5G Advanced Features under Study in 3GPP Release 18



SBA: Service-Based Architecture
 HAPS: High Altitude Platform System
 RAN: Radio Access Network
 MEC: Multi-Access Edge Compute
 NSA: Non-Standalone
 SA: Standalone
 V2X: Vehicle to Everything

WLAN: Wireless Local Area Network
 NR: New Radio
 SFC: Service Functionality Chaining
 NTN: Non-Terrestrial Networks
 LCS: Location Services
 NPN: Non-Public Networks
 LAN: Local Area Networks
 MIMO: Multiple Input Multiple Output

Source: <https://www.3gpp.org/specifications-technologies/3gpp-work-plan>
 Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

5G Advanced
 Release 18
 (2022 - 2023 Dec expected)

5G System and Packet Core:

- Enhanced support for V2X
- High Altitude Platform System (HAPS)
- Dual Active Protocol Stack (DAPS) improvements
- Network slicing enhancements
- Private 5G/Non-Public Network (NPN) enhancements aimed at non-3GPP deployments
- Service Functionality Chaining (SFC) in 5G System
- 5G-enabled fused location service (LCS) capability
- Enhanced 5G Timing Resiliency
- Inclusion of MEC in roaming

RAN:

- Enhancements for eXtended Reality (XR)
- Sidelink Enhancements aimed at unlicensed, power saving enhancements, efficiency enhancements, and so on
- Evolution of Downlink MIMO with enhanced handling of multiple Transmission Reception Points (multi-TRP) and multibeam
- Evolution of Non-Terrestrial Network aimed at 5G NR and IIoT
- Inclusion of traffic characteristics and KPIs for AI/ML
- Evolution of V2X with sidelink enhancements
- Enhancements for Unmanned Aerial Vehicle (UAV)
- Enhanced inter-gNB coordination
- Minimization of Drive Test (MDT) and Self Organizing Networks (SON)
- High Altitude Platform System (HAPS)
- UE Power Savings
- Extended support for frequency bands beyond 52.6GHz
- Carrier Aggregation (CA)/Dual Connectivity (DC) enhancements
- Flexible spectrum integration
- Multicast Broadcast Service (MBS)

Industry verticals:

- V2X
- Non-Terrestrial Networks
- Railway
- Non-3GPP and unlicensed spectrum

• AI/ML KPI

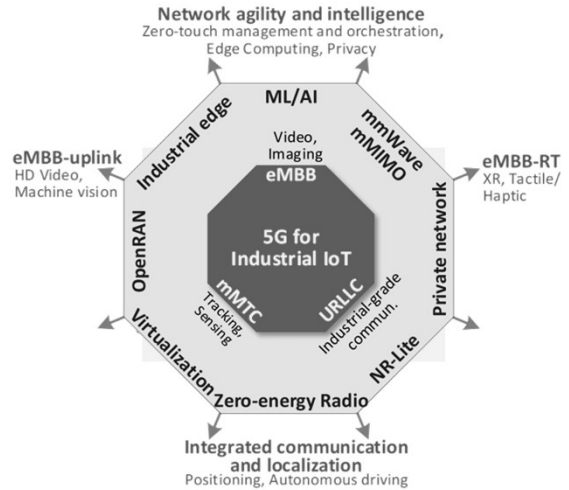
• Multicast Broadcast Service(MBS)

• 비지상 네트워크
 • 철도
 • Non-3GPP 비면허 대역 무선

I. 'MSA와 5G 네트워크'

❖ 5G 발전 방향과 IIoT(예): Beyond-5G vision, 5G architecture, and design trends for IIoT.

- Industrial Edge
- ML/AI
- mmWave/mMIMO
- Private network
- NR-Lite
- Zero-energy Radio
- Virtualization
- OpenRAN



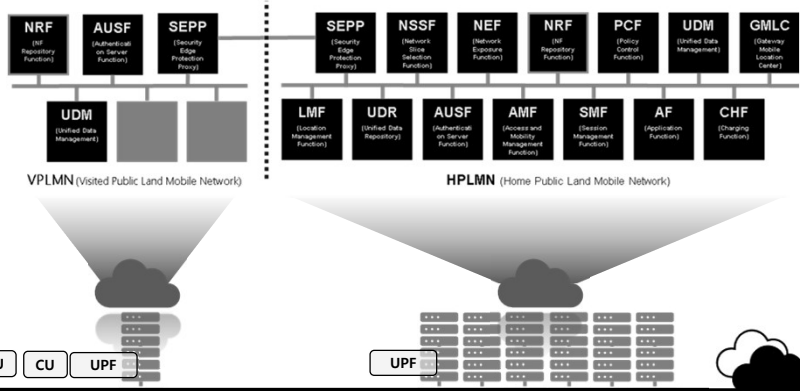
Source: https://www.researchgate.net/figure/Beyond-5G-vision-5G-architecture-and-design-trends-for-IIoT_fig2_354884463

I. 'MSA와 5G 네트워크'

❖ 5G Core의 클라우드화

- 5G Core와 RAN (Radio Access Network)

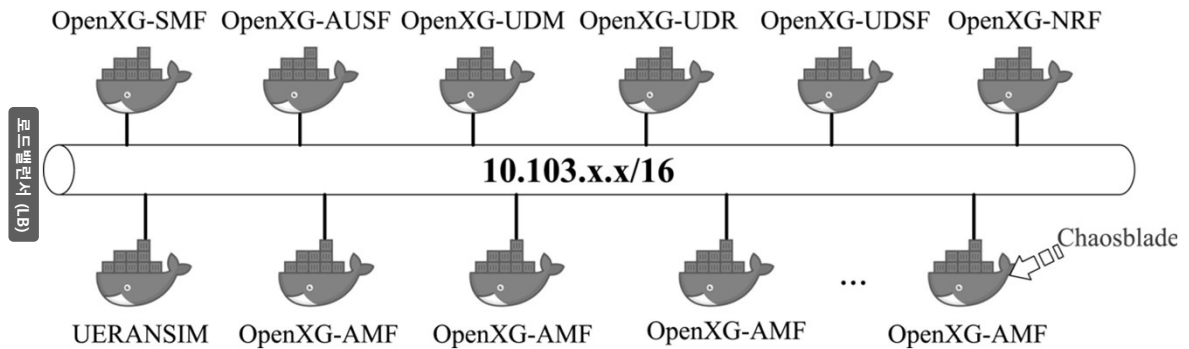
5G Core NF (Network Function)	
CBCF (Cell Broadcast Centre Function)	재난문자 전송 솔루션
CHF (Charging Function)	온라인/오프라인 통합 실시간 과금 솔루션
NEF (Network Exposure Function)	네트워크 기능 개방 솔루션
NRF (NF Repository Function)	5G 망 내 NF 연동 제어 솔루션
NSSF (Network Slice Selection Function)	네트워크 슬라이싱 제어 솔루션
SEPP (Security Edge Protection Proxy)	망 간 로밍 게이트웨이
SMSF (SMS Function)	메시지(SMS) 서비스 인증 및 중계 솔루션



5G Core RAN Reference '5G 융합서비스 테스트베드': Slide 360

I. 'MSA와 5G 네트워크'

❖ Experimental topology.



Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

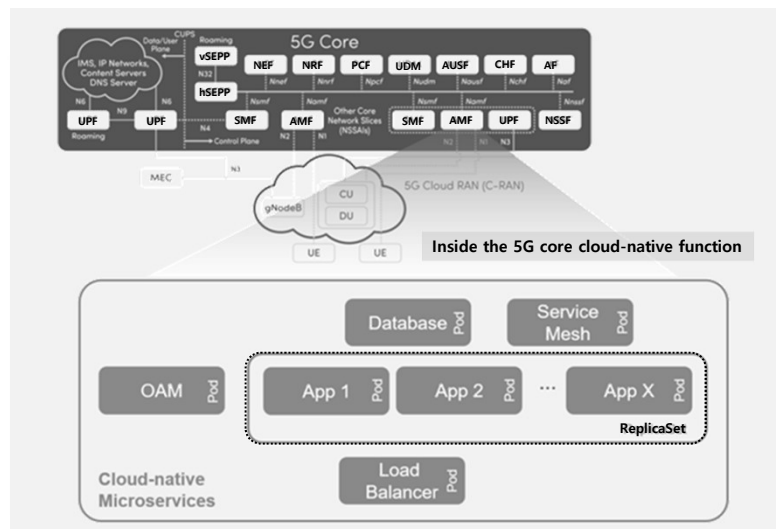
I. 'MSA와 5G 네트워크'

❖ 5G CNF의 MSA

- pods/functions (Kubernetes)

```

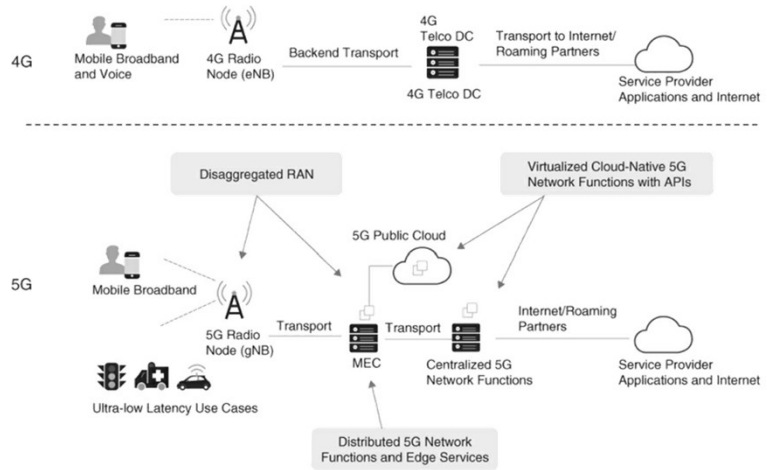
apiVersion: apps/v1
kind: Deployment
metadata:
  name: free5gc-amf-deployment
spec:
  selector:
    matchLabels:
      app: free5gc-amf
  replicas: 3
  template:
    metadata:
      labels:
        app: free5gc-amf
    
```



Source: <https://www.spirent.cn/blogs/why-confidence-in-5g-cloud-performance-begins-with-resilience>

I. 'MSA와 5G 네트워크'

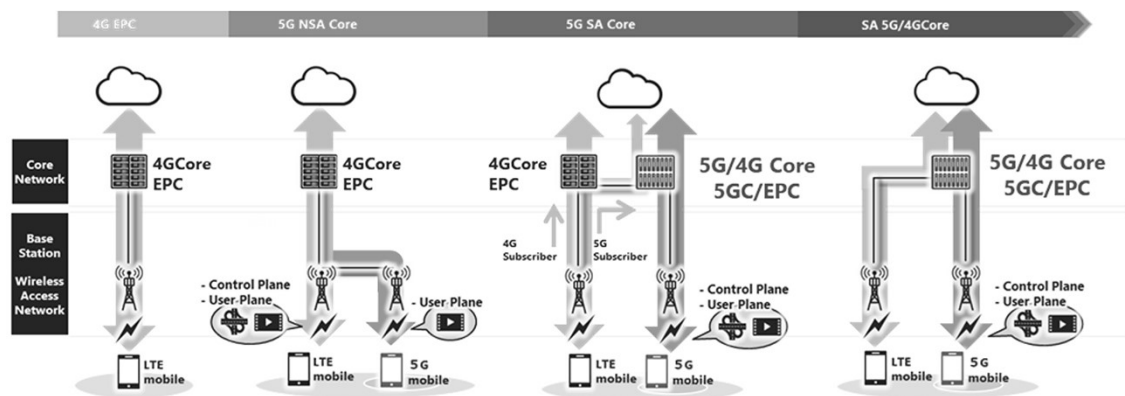
❖ Comparison of 5G and 4G



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

I. 'MSA와 5G 네트워크'

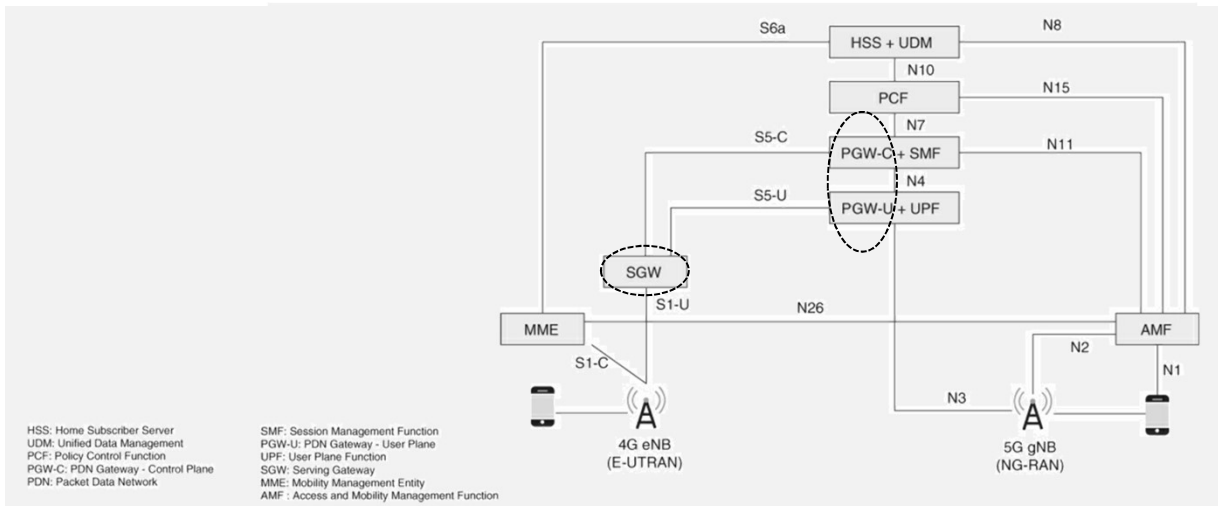
❖ Migration from 4G to 5G



Source: https://www.nec.com/en/press/202202/global_20220222_03.html

I. 'MSA와 5G 네트워크'

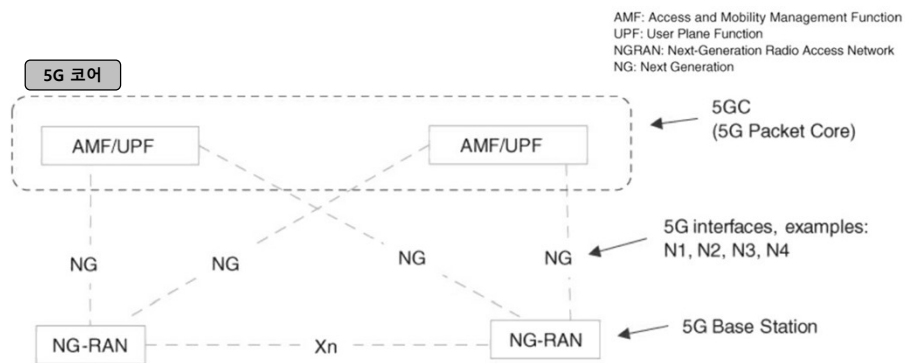
❖ 4G and 5G Interworking



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

I. 'MSA와 5G 네트워크'

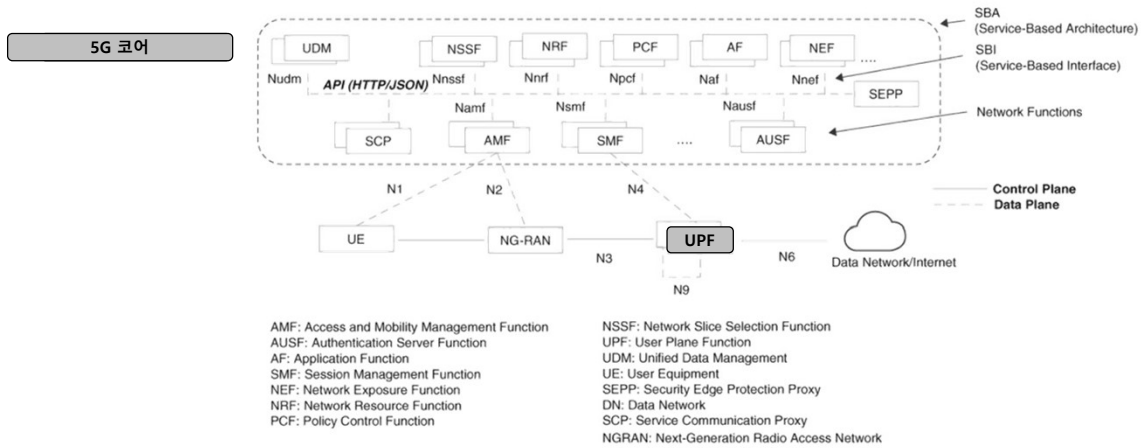
❖ 5G SA Architecture



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

I. 'MSA와 5G 네트워크'

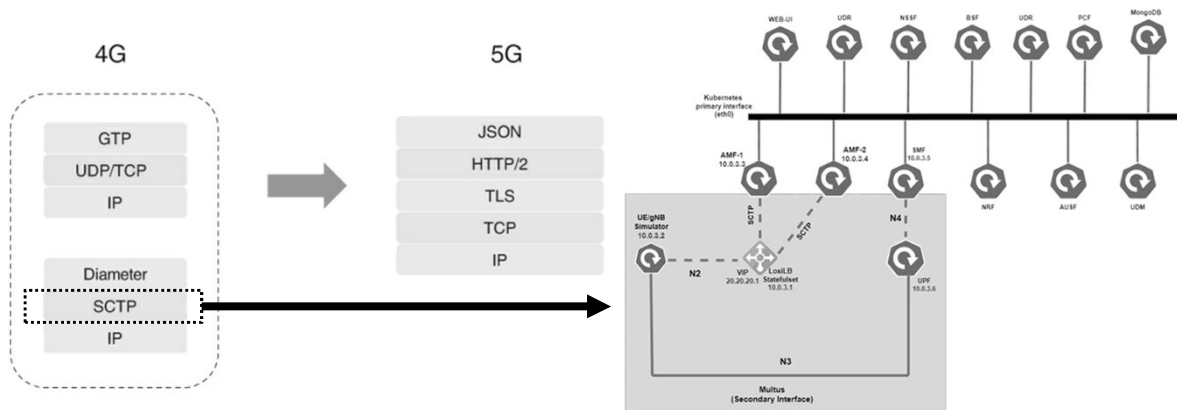
❖ 5G Service-Based Architecture



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

I. 'MSA와 5G 네트워크'

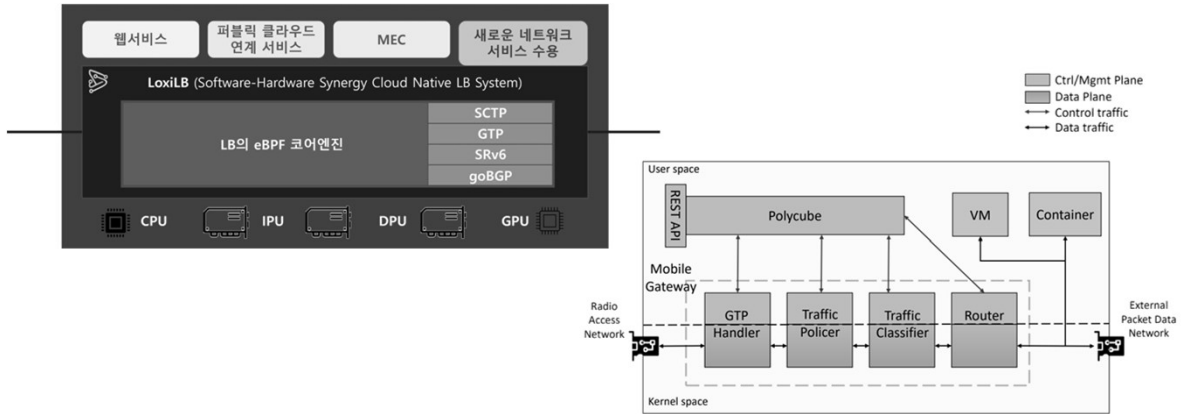
❖ 4G 와 5G 제어평면(Control Plane) 프로토콜 비교



I. 'MSA와 5G 네트워크'

35

- ❖ LoxiLB - eBPF based cloud-native load-balancer for 5G Edge (2023)
- ❖ A Proof-of-Concept 5G Mobile Gateway with eBPF (2020)



Source: <https://ebpf.io/applications/>
 Source: <https://sebymiano.github.io/publication/2020-5g-ebpf-mgw/2020-5g-ebpf-mgw.pdf?fbclid=IwAR3OsfplZGQeBOUFGhH-47XzZTwSjqV7P9E0UQOA-XrGidJmYj0XRoUYUyS>

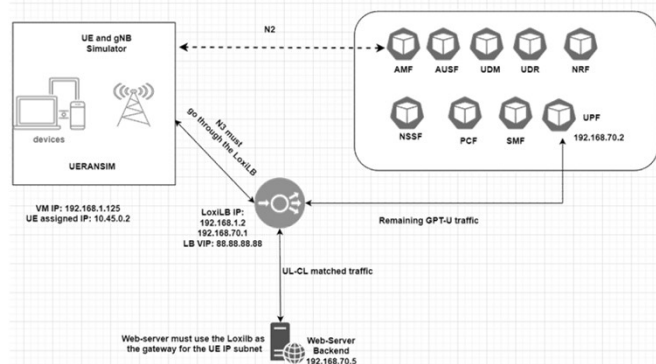
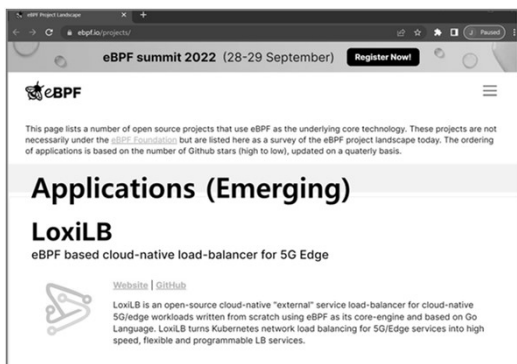
JS Lab

35

I. 'MSA와 5G 네트워크'

36

- ❖ Cloud Native 5G 에지 LB 오픈소스 (예): LoxiLB
- 5G Uplink Classifier Using LoxiLB



Source: <https://futureon.medium.com/5g-uplink-classifier-using-loxilb-7593a4d66f4c>

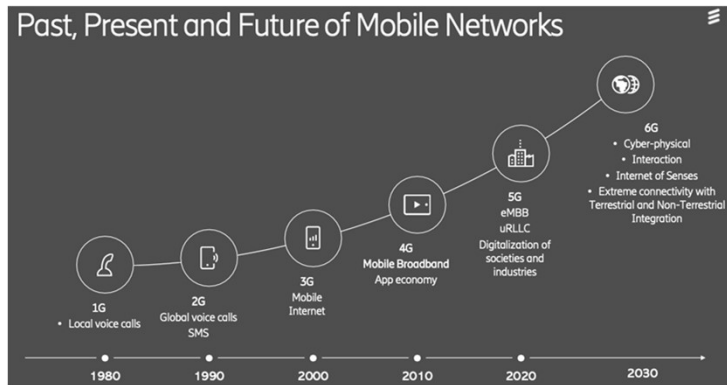
JS Lab

36

I. 'MSA와 5G 네트워크'

❖ Transitioning From 5G To 6G

- **1G Mobile:** AMPS, TOPS, C-450, Radiocom 2000, and All Those Japanese Ones
- **2G:** Mobile Goes Digital
- **3G and 4G:** The Internet Arrives
- **5G:** Connecting All the Things

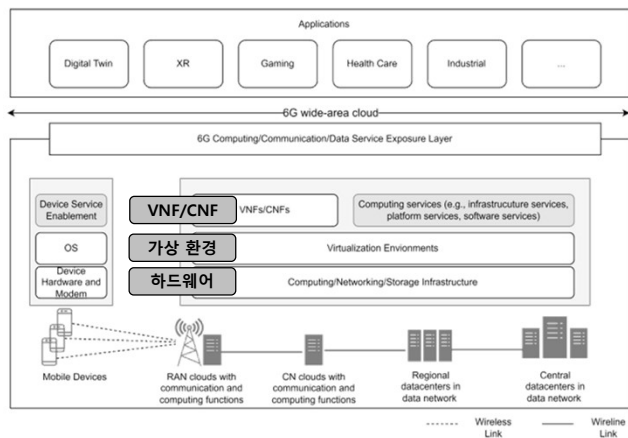


Source: <https://semiengineering.com/edps-transitioning-from-5g-to-6g/>

I. 'MSA와 5G 네트워크'

❖ 6G Cloud-Native System (IEEE)

- **Vision/Challenges/Architecture Framework/Enabling Technology**
 - Wide-area cloud formed on 6G cloud-native system

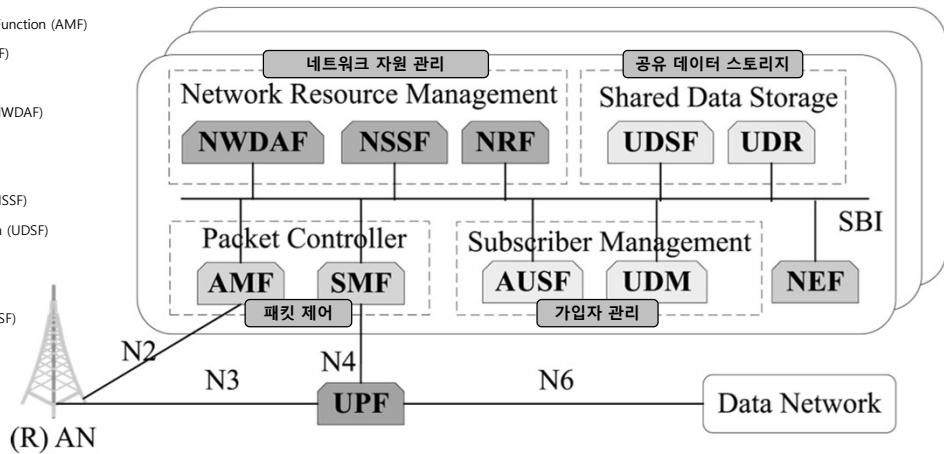


Source: <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9882121>

I. 'MSA와 5G 네트워크'

❖ Service-based architecture for 5G core network.

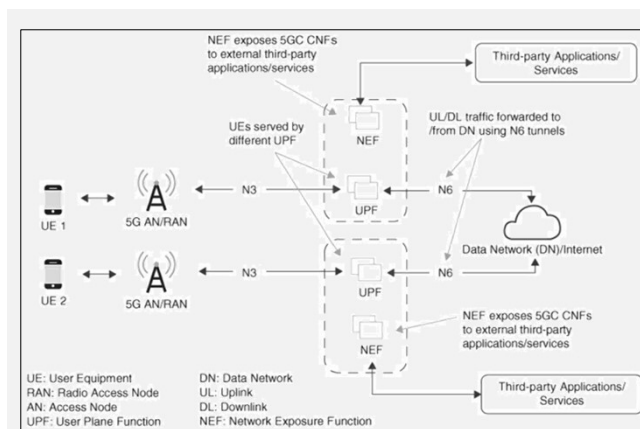
- Access and Mobility Management Function (AMF)
- Session Management Function (SMF)
- User Plane Function (UPF)
- Network Data Analytics Function (NWDAF)
- Network Exposure Function (NEF)
- Network Repository Function (NRF)
- Network Slice Selection Function (NSSF)
- Unstructured Data Storage Function (UDSF)
- Unified Data Management (UDM)
- Unified Data Repository (UDR)
- Authentication Server Function (AUSF)



Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

I. 'MSA와 5G 네트워크'

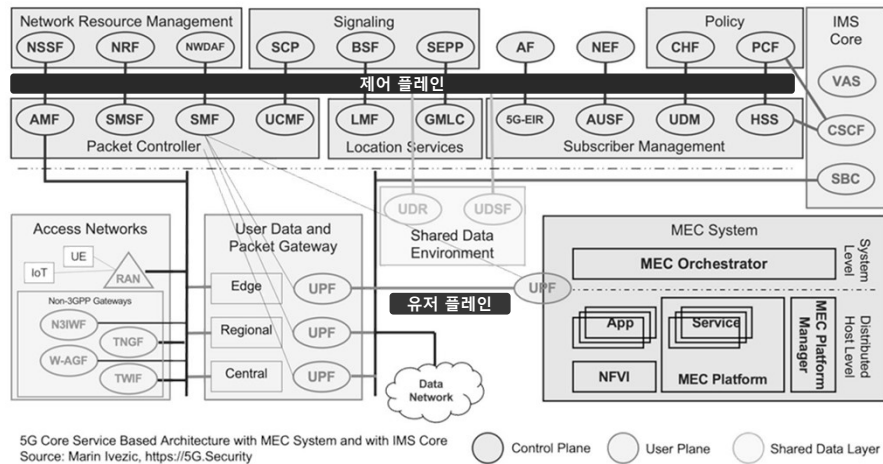
- ❖ NEF의 외부 3rd Party 애플리케이션이나 서비스 연결
- ❖ N6-Based Traffic Forwarding for 5G LAN-Type Service Deployments



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

I. 'MSA와 5G 네트워크'

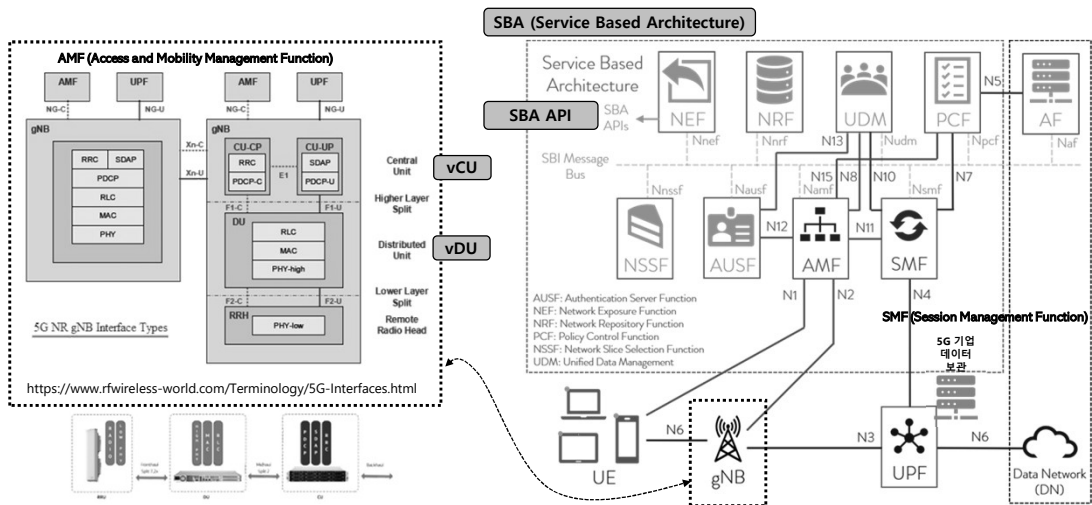
❖ 5G Core SBA along with IMS Core and MEC System. Source: Ivezic 2020



Source: <https://devopedia.org/5g-service-based-architecture>

I. 'MSA와 5G 네트워크'

❖ 5G Service-Based Architecture

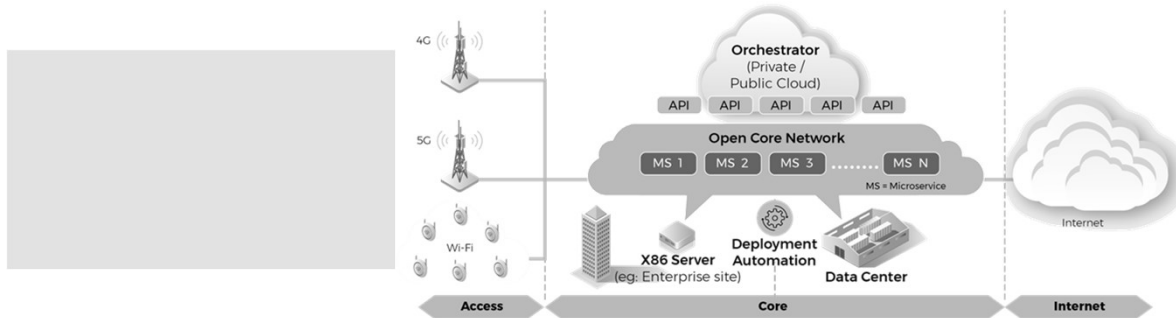


Source: <https://www.metaswitch.com/knowledge-center/reference/what-is-the-5g-session-management-function-smf>

I. 'MSA와 5G 네트워크'

❖ 오픈 코어 네트워크(예): Open Core Network Project Group

- The goal is to innovate on the packet core technologies across any access wireless networks operating on licensed, unlicensed and shared spectrum; develop microservice, orchestration and automation frameworks on OCN platform, and support an ecosystem of developers, OEMs, SIs, MNOs, and ISPs around OCN based solutions.

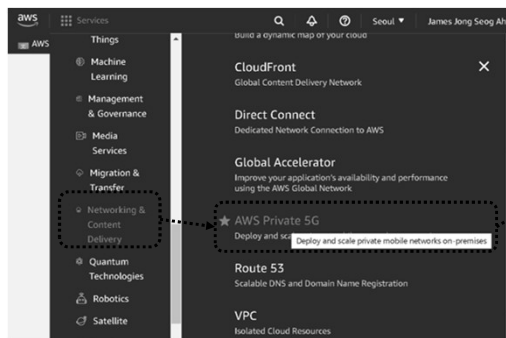


Source: <https://telecominfraproject.com/open-core-network/>

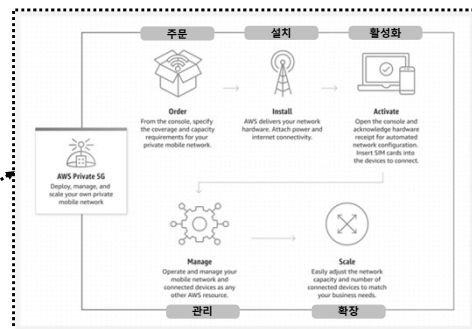
I. 'MSA와 5G 네트워크'

❖ 아마존 AWS Private 5G 서비스

- AWS가 신청 기업으로 AWS Private 5G망 세트를 배송 (3개의 선택 옵션 제공)
 - 1) 5G 코어 UPF는 기업내, Control Plane(AMF, SMF,...)은 AWS 클라우드(Region 또는 Local Zone)
 - 2) 기업내에는 RU만 두고 나머지는 모두 AWS 클라우드에 두는 경우
 - 3) 5G망 Full Set를 기업내에 설치



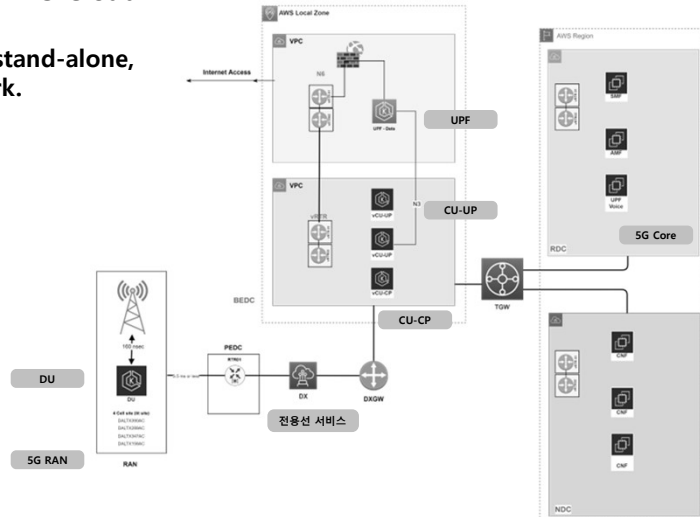
Source: <https://ap-northeast-2.console.aws.amazon.com/console/home?region=ap-northeast-2#>



I. 'MSA와 5G 네트워크'

❖ Deploying DISH's 5G Network in AWS Cloud

- AWS의 RAN 연계
- DISH Network is deploying the first stand-alone, cloud-native, autonomous 5G network.



Source: <https://d2908q01vomqb2.cloudfront.net/c5b76da3e608d34edb07244cd9b875ee86906328/2022/02/27/Figure-3a.png>

I. 'MSA와 5G 네트워크'

❖ 아마존 AWS Private 5G 서비스 Price

- Example 1: IoT devices in a manufacturing facility

	Cost calculation	Total cost
AWS Private 5G radio unit	1 x \$7,200 x 2	\$14,400
Data transfer intra-Region	13 GB x \$0.02 x 2	\$0.52
60-day cost		\$14,400.52

- Example 2: Video streaming from security cameras at a construction site

	Cost calculation	Total cost
AWS Private 5G radio unit	1 x \$7,200 x 2	\$14,400
60-day cost		\$14,400

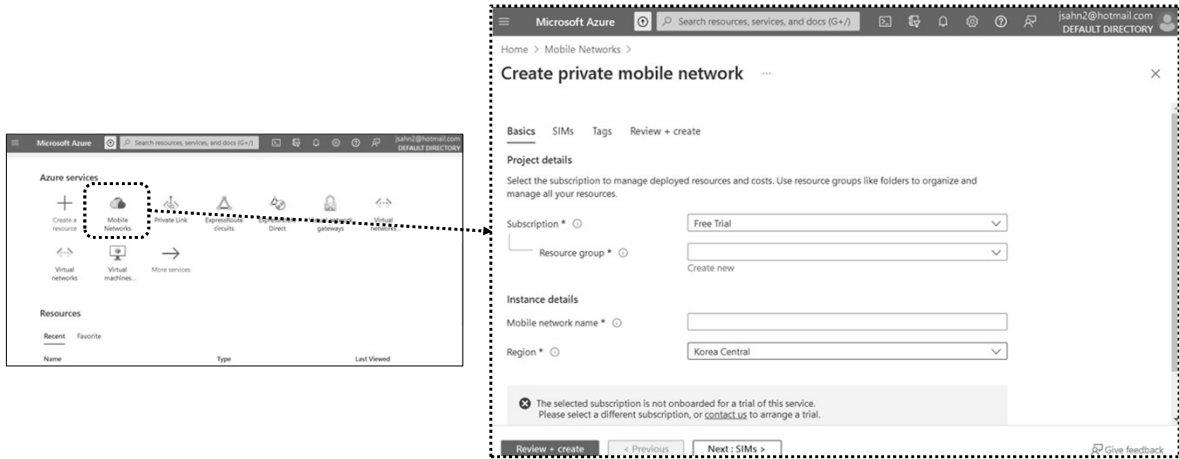
- Example 3: Higher education campus—Outdoor coverage for staff

	Cost calculation	Total cost
AWS Private 5G radio unit	1 x \$7,200 x 2	\$14,400
Data transfer out, under the global monthly AWS Free Tier	100 GB x \$0.00 x 2	\$0
Data transfer out to web services and to tablets	2,760 GB x \$0.09 x 2	\$496.80
60-day cost		\$14,896.80

Source: <https://ap-northeast-2.console.aws.amazon.com/console/home?region=ap-northeast-2#>

I. 'MSA와 5G 네트워크'

❖ 마이크로소프트 Azure 'private mobile network'



Source: <https://portal.azure.com/#view/HubsExtension/BrowseResource/resourceType/Microsoft.MobileNetwork%2FmobileNetworks>

I. 'MSA와 5G 네트워크'

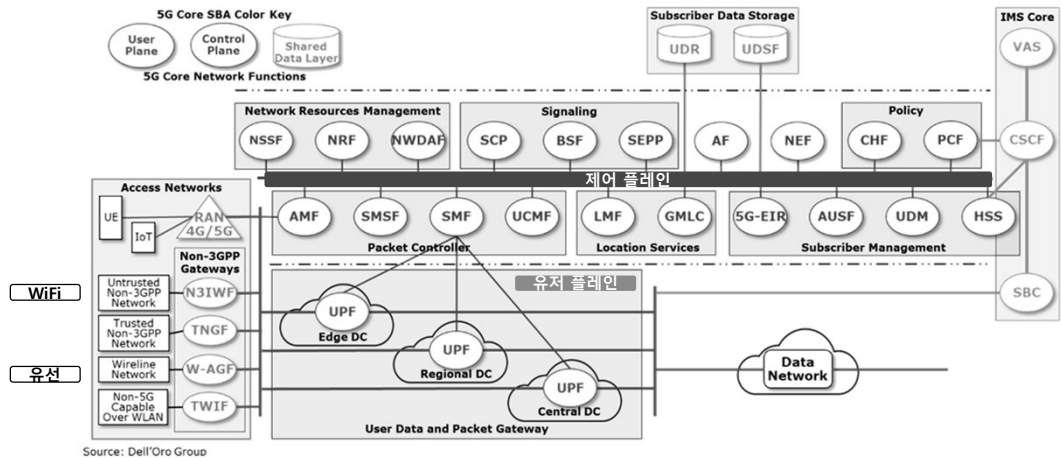
❖ Comparing SOA, microservices, SBA and monolithic architecture.

Architecture \ Criterion	SOA	μ-service architecture	SBA	Monolithic
Agility	Low	High	Medium	Low
Deployment	Low	High	Medium	Low
Testability	Low	High	Medium	Medium
Scalability	Medium	High	Medium	Low
Performance	Low	Medium	Medium	High
Simplicity	Low	Medium	Medium	High

Source: Comparing SOA, microservices, SBA and monolithic architecture. Source: 5G-PPP 2018, table
 Source: <https://devopedia.org/5g-service-based-architecture>

I. 'MSA와 5G 네트워크'

❖ 5G System with 5G Core Service Based Architecture(SBA) + IMS Core

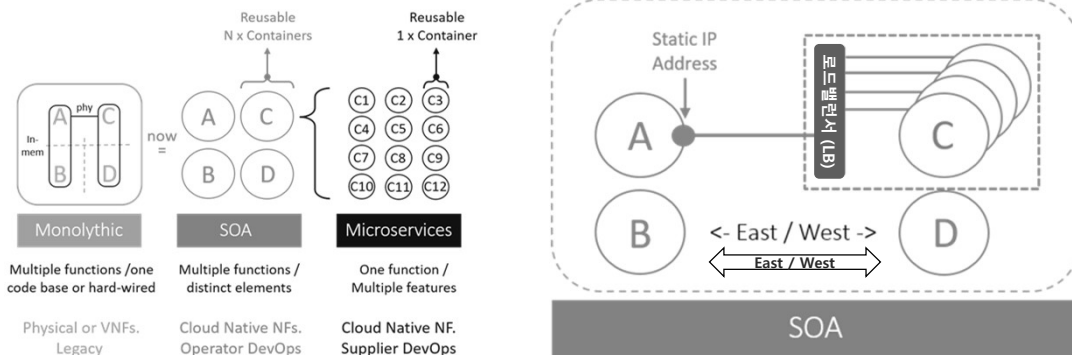


Source: <https://www.delloro.com/5g-core-are-we-ready/>

I. 'MSA와 5G 네트워크'

❖ 제조사 (예): Metaswitch

- 5G Caught Up in a Service Mesh
- Service Oriented Architectures

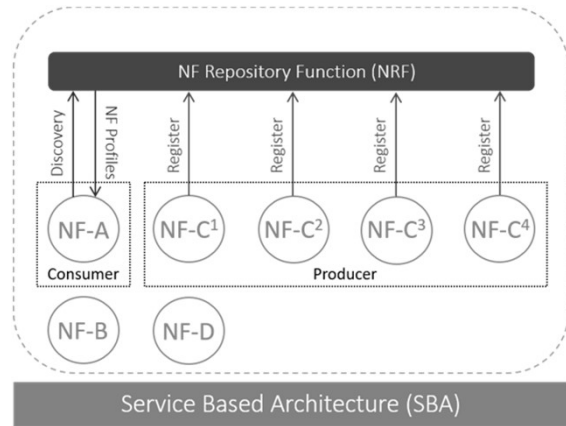


Source: <https://www.metaswitch.com/blog/the-service-communication-proxy-5g-caught-up-in-a-service-mesh>

I. 'MSA와 5G 네트워크'

❖ 제조사 (예): Metaswitch

- The NRF meets the requirement of our macro SOA controller in the 5G SBA

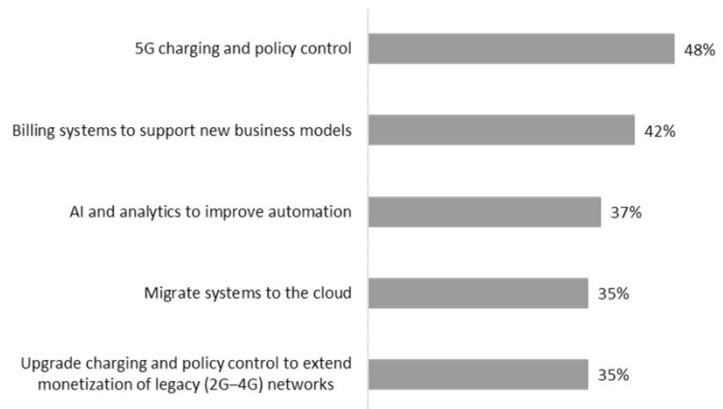


Source: <https://www.metaswitch.com/blog/the-service-communication-proxy-5g-caught-up-in-a-service-mesh>

I. 'MSA와 5G 네트워크'

❖ Telco BSS priorities

What are your top investment priorities to improve monetization over the next 18 months? (Select 3.)

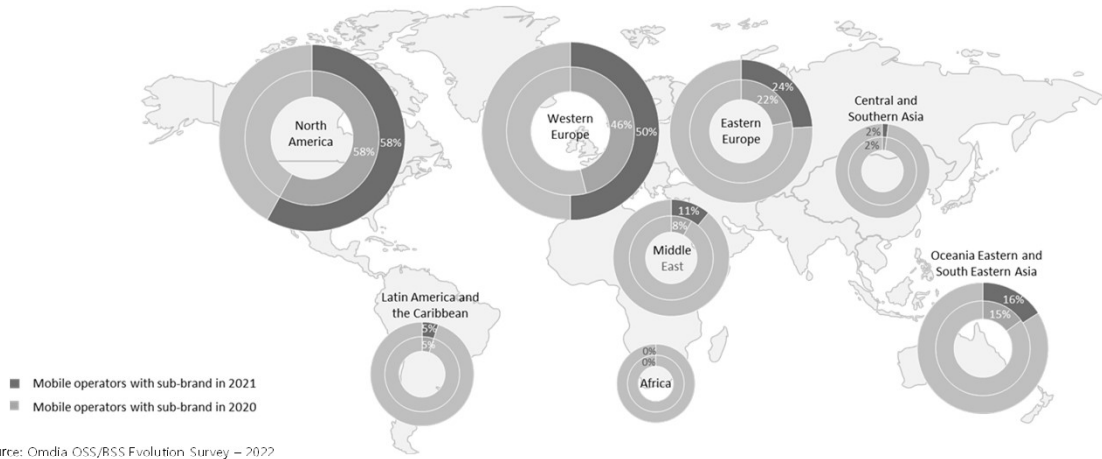


BSS (Business Support System): 비즈니스 지원 시스템의 줄임말
BSS는 통신 조직이 모든 고객 대면 활동을 관리하고 간소화하는 데 도움이 되는 다양한 소프트웨어 프로그램

Source: Source: Omdia OSS/BSS Evolution Survey – 2022
Source: <https://www.oracle.com/a/ocom/docs/corporate/analystrelations/technology-analysis-converged-charging-in-5g.pdf>

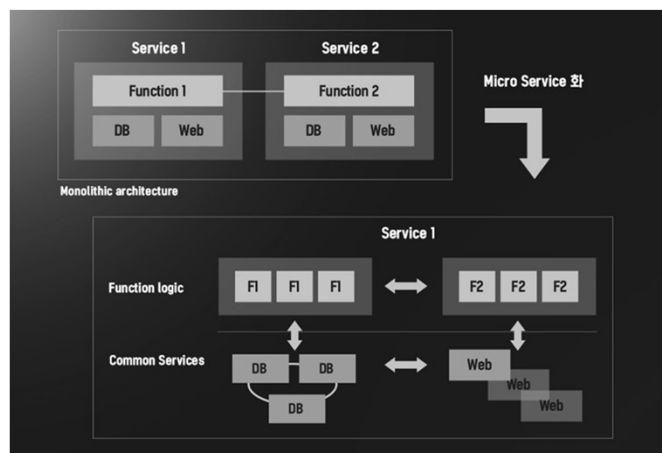
I. 'MSA와 5G 네트워크'

- ❖ Adoption of sub-brands by MNOs around the world
 - target specific consumer and enterprise segments



I. 'MSA와 5G 네트워크'

- ❖ 5G 인프라와 마이크로 서비스 아키텍처
 - Function(임의의 기능)/DB/Web 기능이 하나의 모듈에 들어가 있는 모노리틱 아키텍처를 MSA화

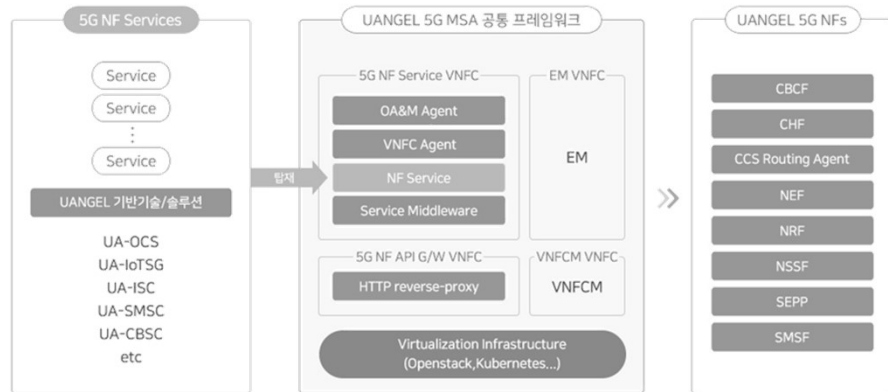


Source: <https://news.sktelecom.com/112011>

I. 'MSA와 5G 네트워크'

❖ 5G 코어 네트워크의 Micro Service Architecture(MSA) 개발(예)

- 유엔젤: Service-Based Architecture(SBA)와 Micro Service Architecture(MSA) 최적화 개발, 오픈소스들을 활용, 서비스 개발 환경인 CI/CD 환경 구축을 통해 Cloud Native 구조

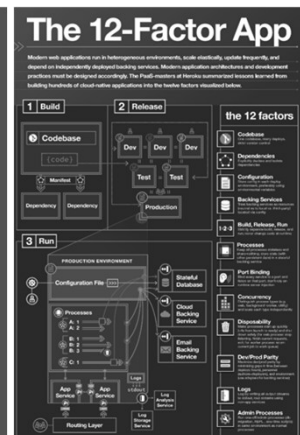
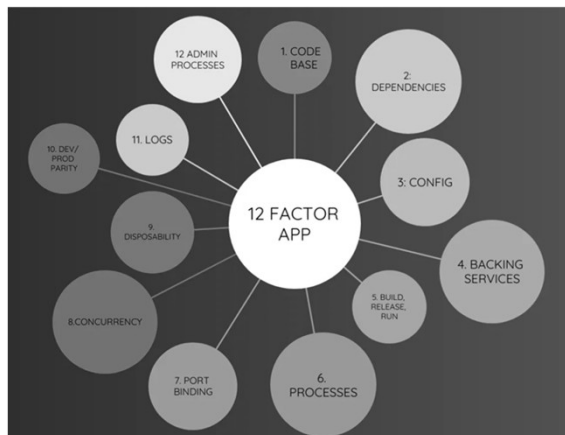


Source: <http://www.uangel.com/kr/index.php/products/5g/5g-core/>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

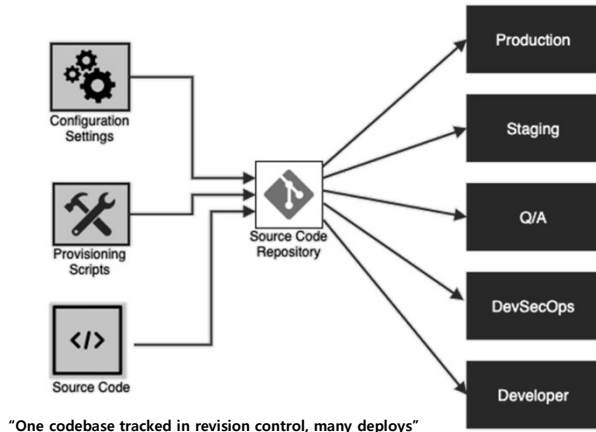


Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes



Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/codebase.png?itok=hOd-Qv8N
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

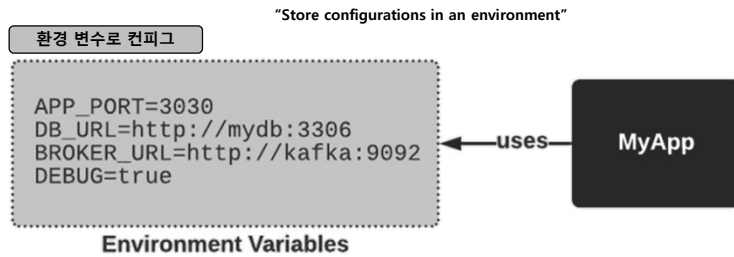


Source: <https://developer.ibm.com/developer/default/articles/creating-a-12-factor-application-with-open-liberty/images/images02.png>
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

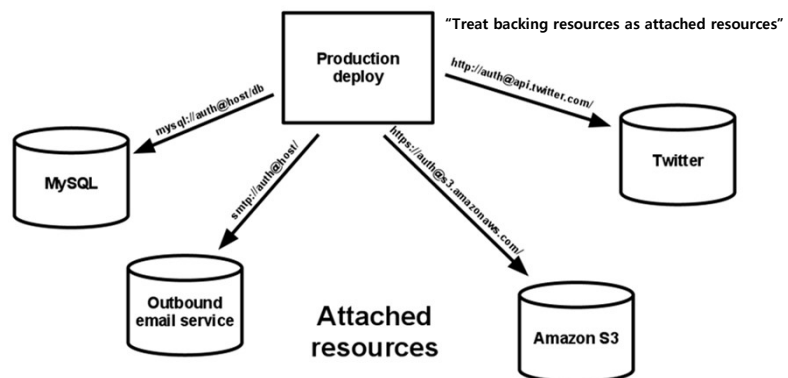


Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/config.png?tok=BmjfdjDH
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

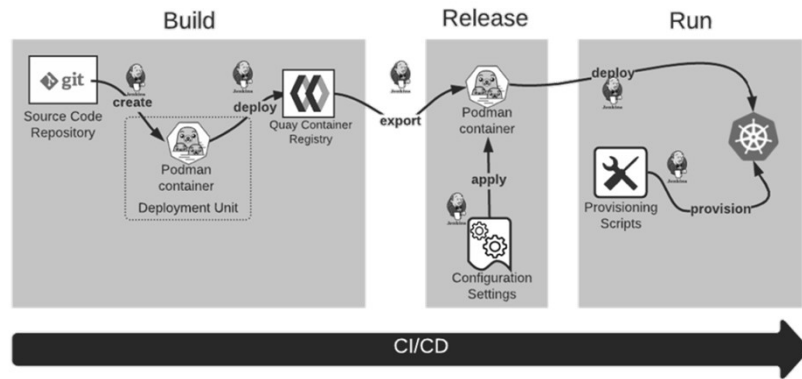


Source: <https://12factor.net/images/attached-resources.png>
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

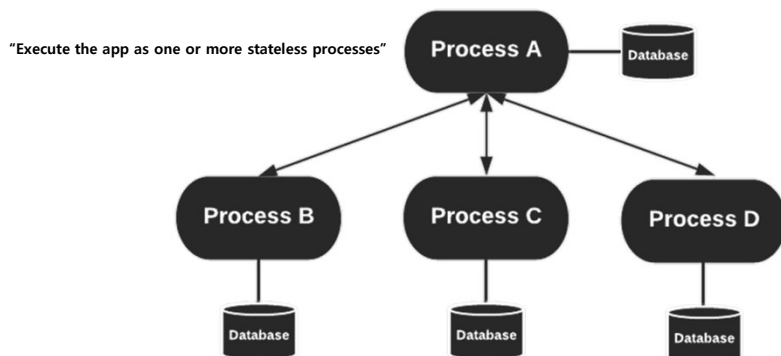


Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/buildreleaserun.png?itok=tU10QwgC
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes



Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/process.png?itok=sKKO87wh
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

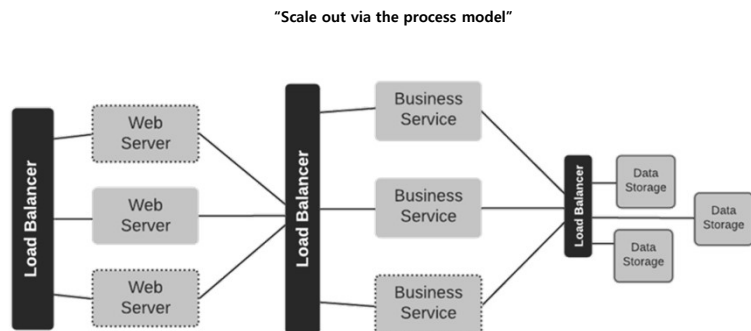


Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/portbindings.png?itok=d8Le0wh-
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes



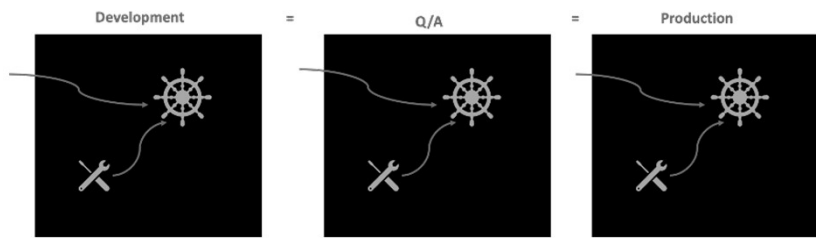
Source: https://www.redhat.com/architect/sites/default/files/styles/embed_large/public/2021-02/concurrency.png?itok=aqNxheba
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

개발/적용 동등성: "Keep development, staging, and production as similar as possible"

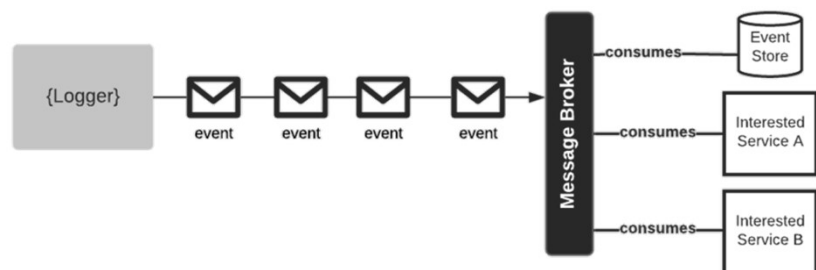


Source: <https://developer.ibm.com/developer/default/articles/creating-a-12-factor-application-with-open-liberty/images/image10.png>
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 12 Factor App in Microservices Architecture

- Codebase
- Dependencies
- Config
- Backing Services
- Build, release, and Run
- Processes
- Port Binding
- Concurrency
- Disposability
- Dev/prod parity
- Logs
- Admin processes

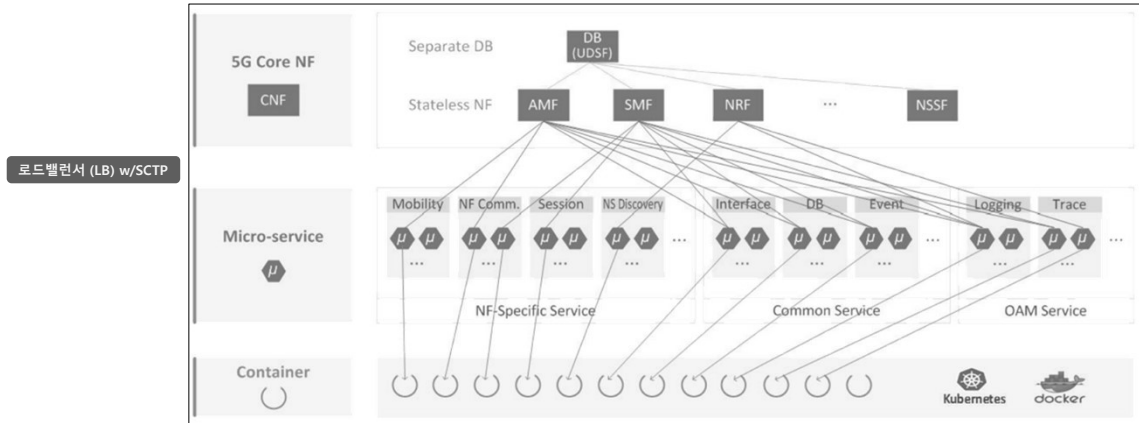


Source: <https://developer.ibm.com/developer/default/articles/creating-a-12-factor-application-with-open-liberty/images/image10.png>
Source: <https://medium.com/javarevisited/do-you-know-about-the-12-factor-app-in-microservices-architecture-50bd34551bd8>

I. 'MSA와 5G 네트워크'

❖ 제조사 (예): Cloud Native Architecture

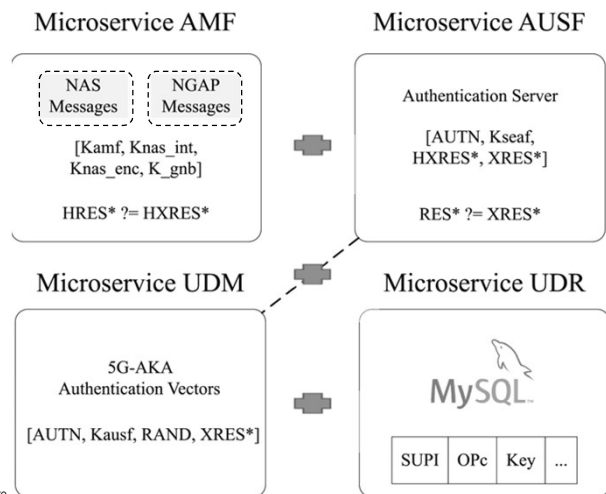
• Samsung 5G Core: Cloud Native Architecture



Source: <https://images.samsung.com/is/content/samsung/p5/global/business/networks/insights/white-paper/5g-core-vision/5G-Core-Vision-Samsung-5G-Core-Vol.1.pdf>

I. 'MSA와 5G 네트워크'

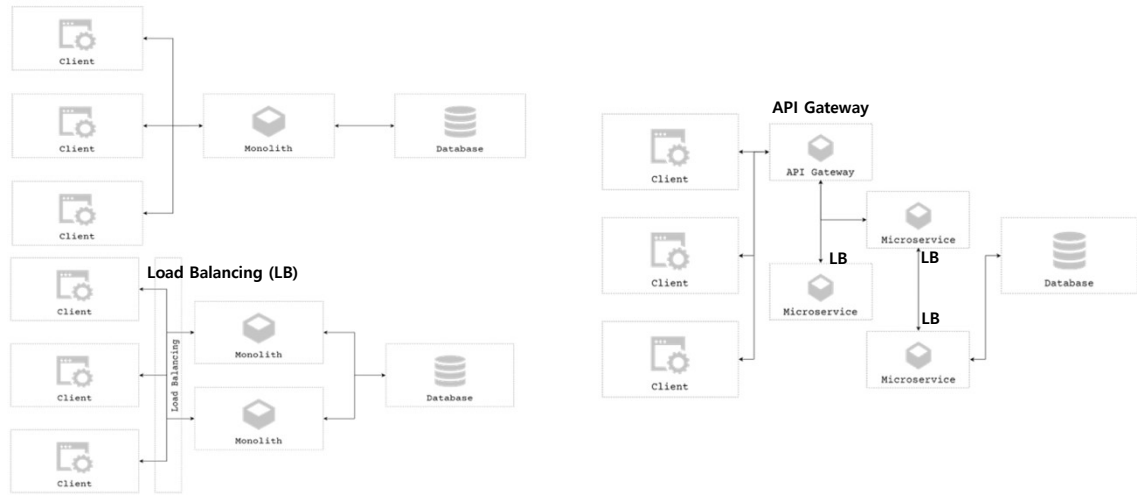
❖ Function decoupling (complaint with 3GPP)



The current monolithic OpenXG-AMF is decoupled into multiple microservices as depicted in the figure.
Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

I. 'MSA와 5G 네트워크'

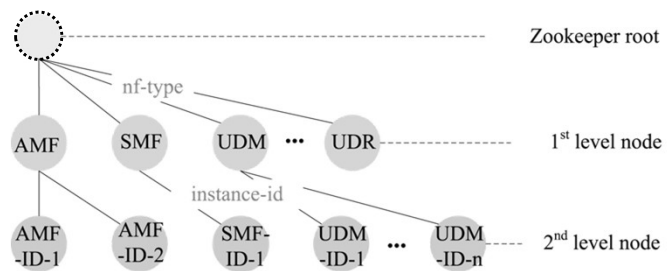
❖ monolithic vs. monolithic with load balancing vs. microservices architecture.



Source: <https://www.mdpi.com/2071-1050/14/4/2173>

I. 'MSA와 5G 네트워크'

❖ A tree-like data storage based on Zookeeper



```

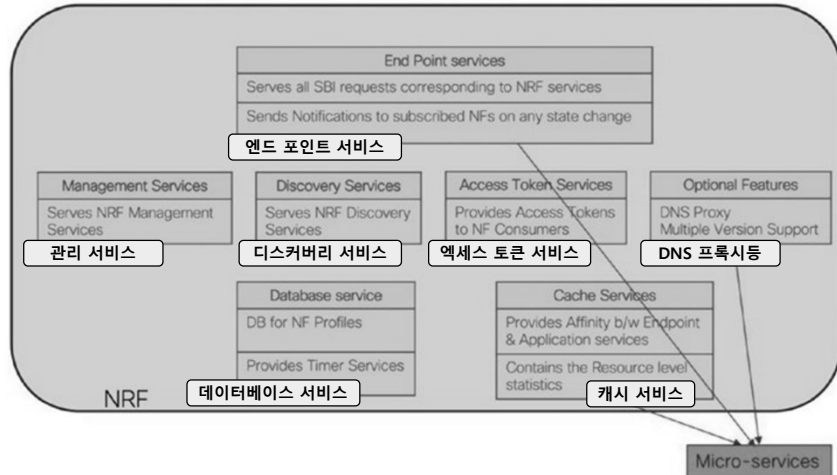
detailed information (NF Profile)
nfInstanceId: ba12a079-f98f-4598-bfb4-ec65b7178c7c
nfType: AMF
nfStatus: REGISTERED
ipv4Addresses: [192.169.0.3]
nfServices: [{serviceName: namf-comm, versions: [{apiVersionInUri:v1,
apiFullVersion:none}], scheme:https, nfServiceStatus:REGISTERED}]
    
```

주키퍼(zookeeper)는 분산 애플리케이션을 위한 코디네이션 시스템이며, 안정적인 서비스를 할 수 있도록 분산되어 있는 각 애플리케이션의 정보를 중앙에 집중하고 구성 관리, 그룹 관리 네이밍, 동기화 등의 서비스를 제공 (경쟁 가능한 대체는?)

Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

I. 'MSA와 5G 네트워크'

❖ NRF의 마이크로서비스(예) Bundling of microservices within an NRF



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

I. 'MSA와 5G 네트워크'

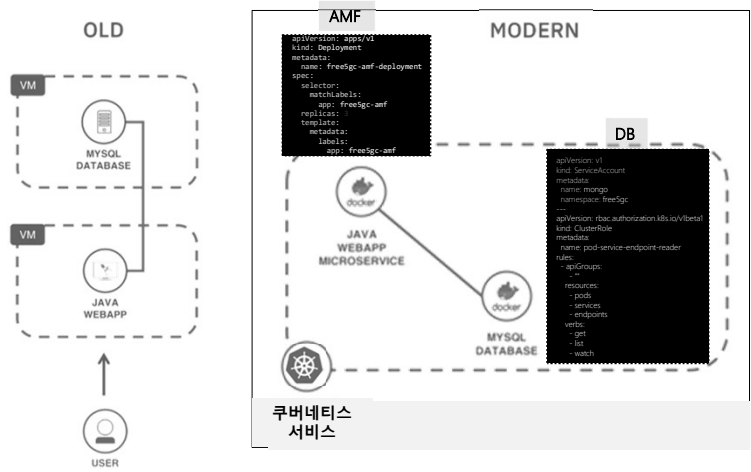
❖ CSP(예): 클라우드 앱 현대화 방식 7가지

- Retire: 소명을 다한 앱은 그만 놓아주기
- Replace: 기존 앱을 SaaS, 상용, 혹은 오픈소스 앱으로 대체하기
- Relocate: 클라우드로 앱을 이전하기
- Replatform: 운영 가치가 있는 요소는 리플랫폼
- Reuse: 재사용-기존 앱의 데이터 모델, 서비스, API 등을 재사용
- Refactor: 리팩터링 - 기존 코드를 리팩터링해 성능, 보안, 유지보수 용이성을 개선
- Rebuild: 재구축 - 기능 개선, 결점 보완 혹은 기술적 부채 감축을 위해 모듈을 재구축

Source: <https://www.ciokorea.com/news/262720#csidx2c4c411f6f3346c829c9dbc37a8610b>

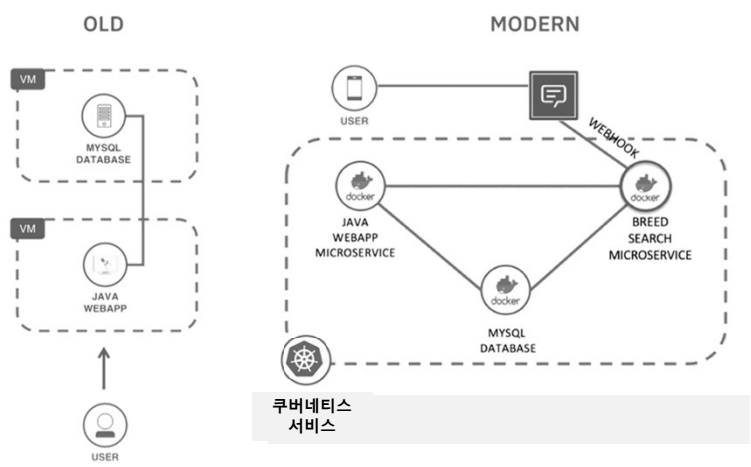
I. 'MSA와 5G 네트워크'

❖ Modern App (예)



I. 'MSA와 5G 네트워크'

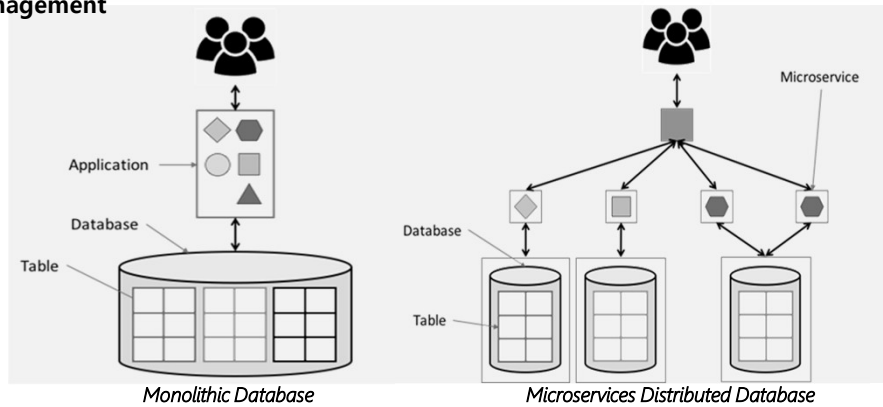
❖ Modern App (예)



I. 'MSA와 5G 네트워크'

❖ Refactoring (from Monolithic Module to MSA)

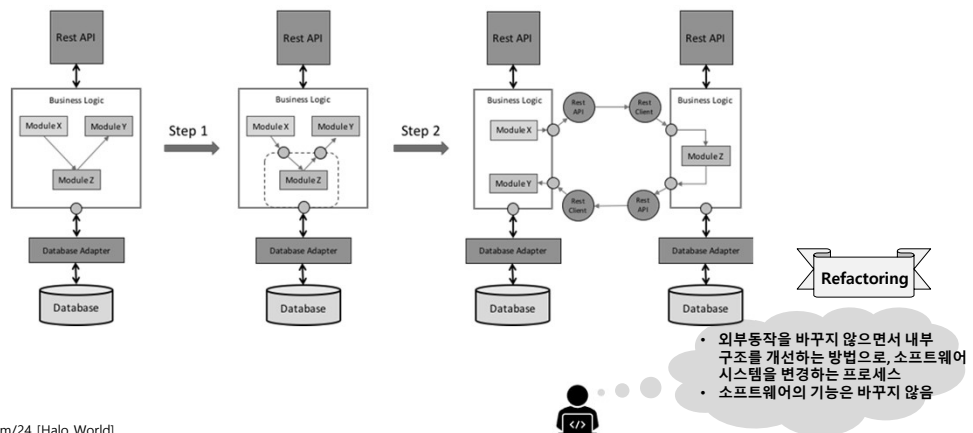
- Decentralized business and messaging rules
- Decentralized governance
- Decentralized data management



I. 'MSA와 5G 네트워크'

❖ Refactoring (from Monolithic Module to MSA)

- 서비스 모듈간 메시지 송수신 필요 (API 사용)



Source: <https://haloworld.tistory.com/24> [Halo World]



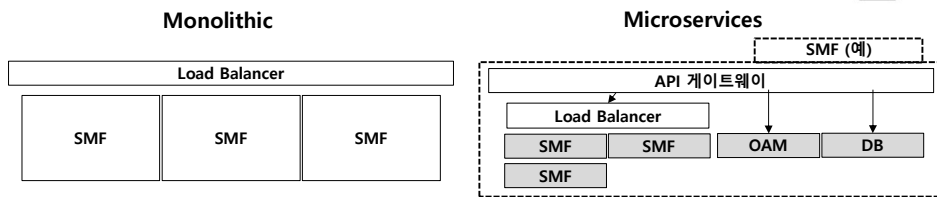
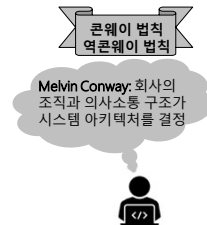
I. 'MSA와 5G 네트워크'

❖ 조직의 Learning Curve 고려

- 단일 마이크로서비스 (Standalone Microservice) 많이 필요시
- 과도한 의존성으로 시간이 많이 필요하고 코드의 품질이 낮아질 때
- 한가지 요소로 애플리케이션 장애 시

❖ 마이크로서비스 전환 시 추가 기능 고려

- 비즈니스 기능을 위한 서비스 연결
- 스탠드얼론 and/or 서비스의 부분 적용
- 각 엔지니어링 팀은 비즈니스 영역의 이해하고 책임을 소유

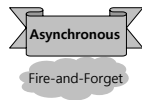
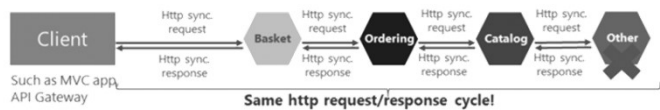


I. 'MSA와 5G 네트워크'

❖ Synchronous vs. async communication across microservices

Anti-pattern

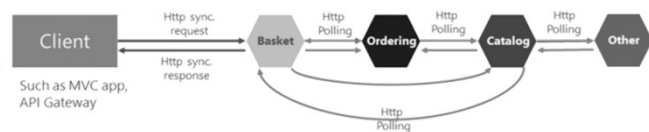
Synchronous
all request/response cycle



Asynchronous
Comm. across internal microservices (EventBus: like AMQP)



"Asynchronous"
Comm. across internal microservices (Polling: Http)



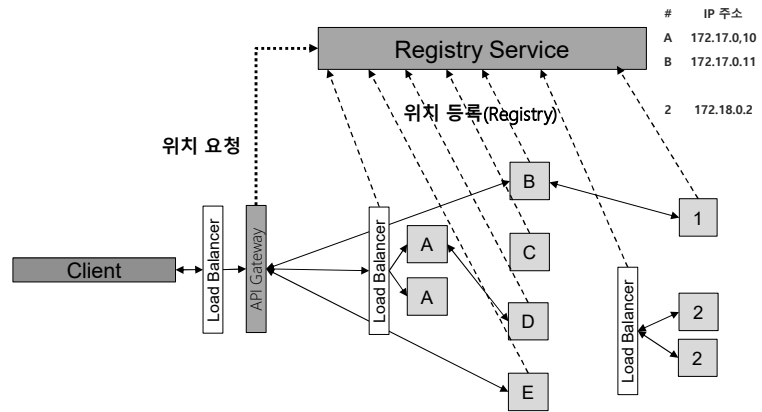
Source: <https://www.emagiz.com/blog/loosely-coupled-applications-in-a-microservice-architecture/>



I. 'MSA와 5G 네트워크'

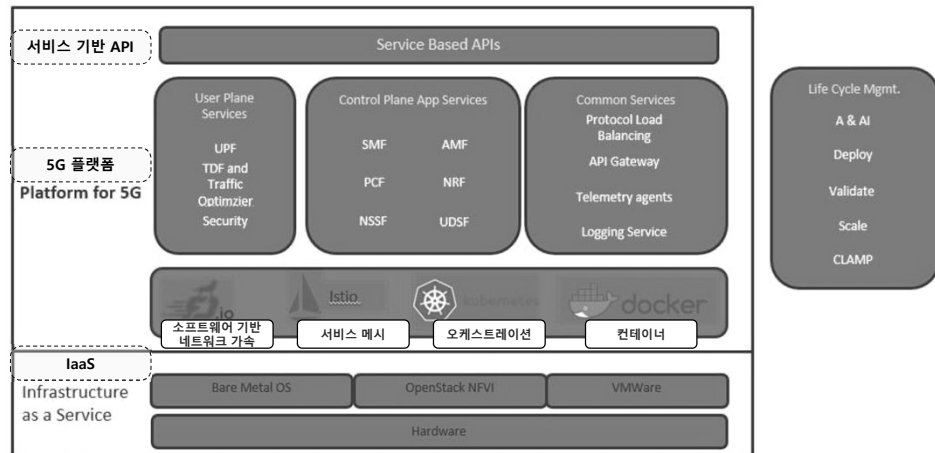
❖ 로드밸런서 추가 시 Service registry

- API Gateway는 모든 서비스에 대한 IP 주소를 알아야 하며 이의 DB 필요
- Registry 데이터의 안정성을 위해 오픈소스 사용(Consul이나 SkyDNS)



I. 'MSA와 5G 네트워크'

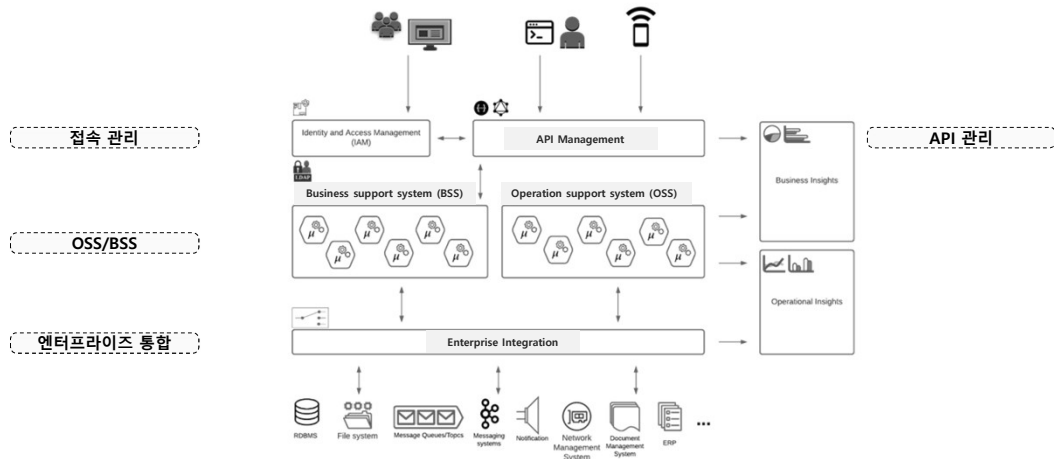
❖ The Role of API Gateways



Source: <https://techblog.comsoc.org/2021/03/22/787465/>

I. 'MSA와 5G 네트워크'

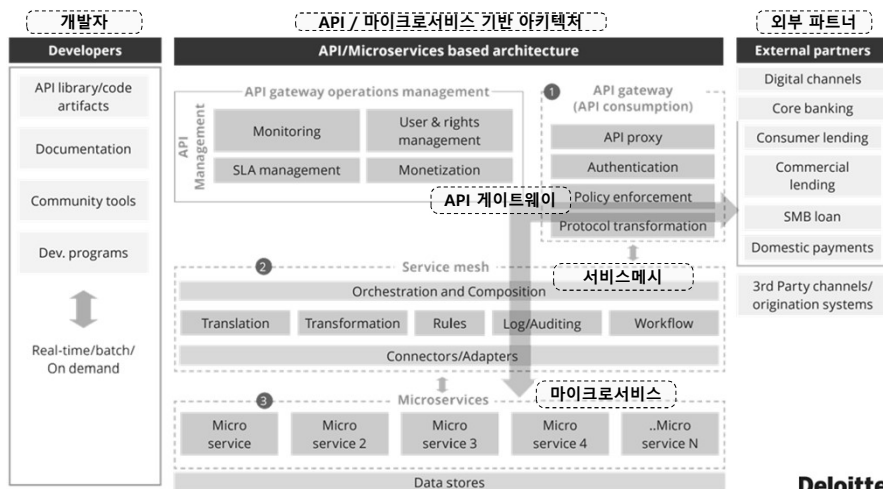
❖ 서비스 모델(예): Reference Architecture for telecom enterprise platform



Source: <https://medium.com/codex/reference-architecture-for-a-telecom-enterprise-application-platform-257769a4a8d0>

I. 'MSA와 5G 네트워크'

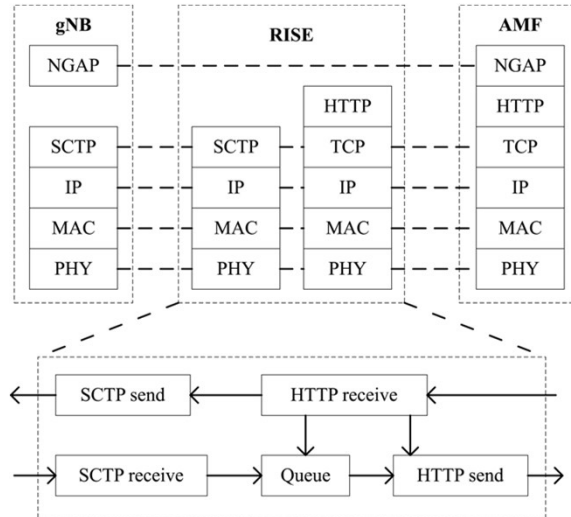
❖ Microservices-based architecture (예)



Source: <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/financial-services/us-enabling-platform-banking-pov.pdf>

I. 'MSA와 5G 네트워크'

❖ The software architecture of RISE.



Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

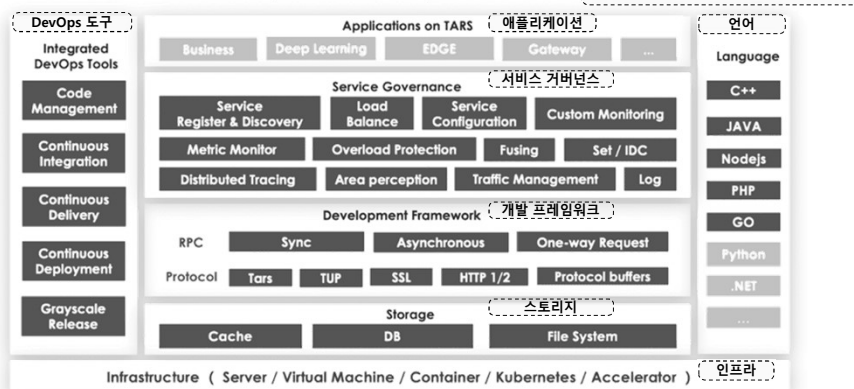
I. 'MSA와 5G 네트워크'

❖ 리눅스재단의 TARS 프로젝트

TARS offers a Microservice Ecosystem

Build your microservices platform with TARS

TARS는 마이크로서비스 생태계를 제공

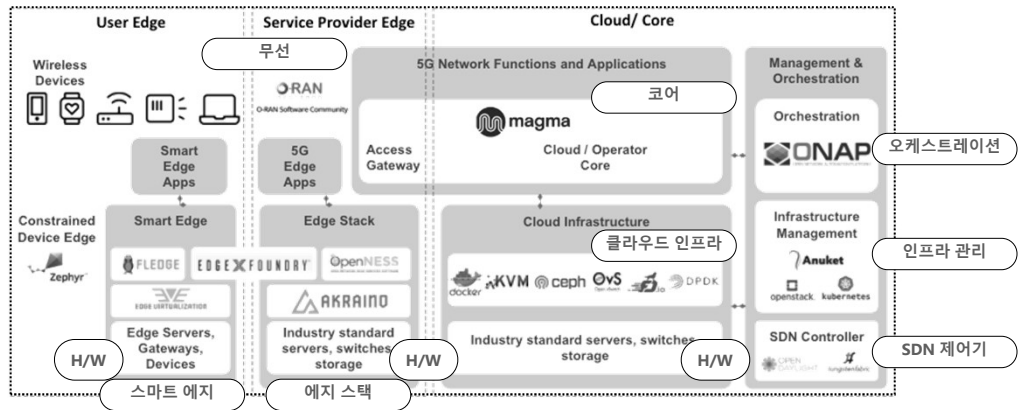


Source: <https://www.linuxfoundation.org/blog/the-tars-foundation-the-formation-of-a-microservices-ecosystem/>

I. 'MSA와 5G 네트워크'

❖ 리눅스재단(LF): ONAP's Cloud Native Journey (오케스트레이션)

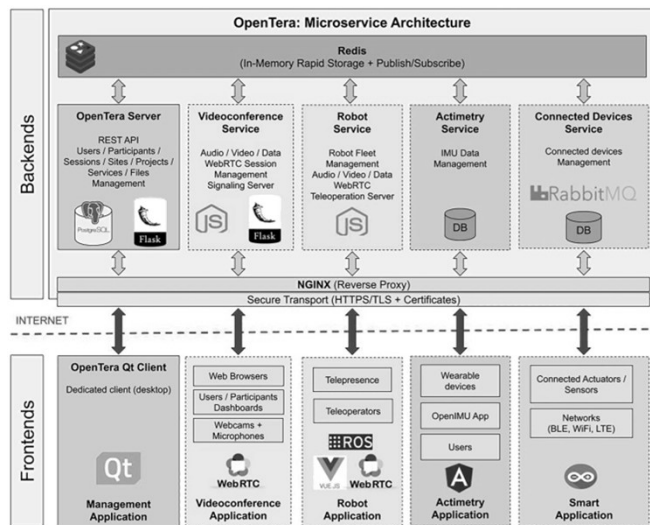
LF Open Source Component Projects for 5G



Source: <https://www.lfnetworking.org/5g-super-blueprint/>

I. 'MSA와 5G 네트워크'

❖ OpenTera microservice architecture



Source: <https://link.springer.com/article/10.1007/s12553-021-00636-5>

I. 'MSA와 5G 네트워크'

❖ CSP의 오픈소스 적용 (예): Free5GC

- **deploy the free5gc core**
 - Kubernetes cluster created by Platform9 Managed Kubernetes. You can create your account here.
 - KubeVirt should be enabled to create Virtual Machines on Ubuntu 18.04 with Linux kernel version 5.0.0-23-generic.
 - Gtp5g Kernel module on Ubuntu Virtual Machine.
 - SCTP support in Kubernetes Services. (Refer to the Appendix section)
 - Kubernetes Cluster backed by Calico CNI or any CNI with the capability to provide static IPs to pods.



Source: <https://platform9.com/blog/running-free5gc-on-platform9-managed-kubernetes/>

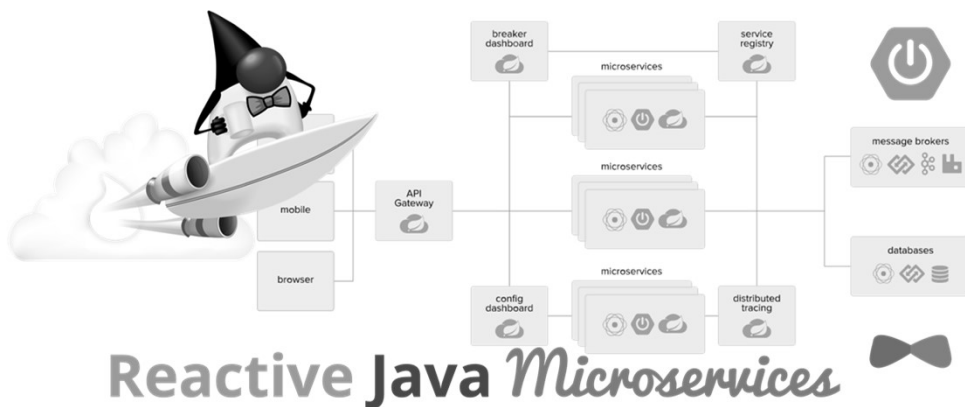
Source: https://aws.amazon.com/blogs/industries/5g-core-implementation-on-amazon-elastic-kubernetes-service-anywhere-on-bare-metal-2/?fbclid=IwAR1r57SDZ0tljU3f4no-nCC7fdV8nj6p8mCmFWFVzerKwFLX_IBUtiSZNc



I. 'MSA와 5G 네트워크'

❖ Reactive Microservices

- **Reactive Java Microservices**



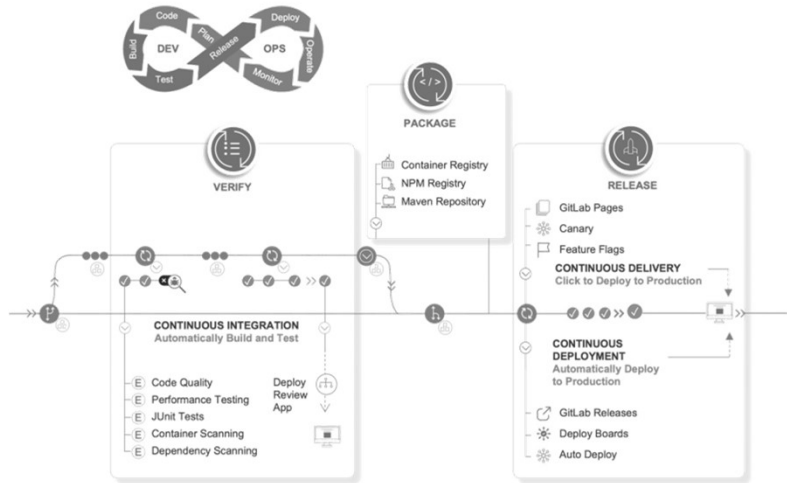
Source: <https://medium.com/@sureshbabug/microservices-part1-introduction-to-springboot-spring-webflux-and-spic-test-frameworks-with-18e8c9bcb73>



I. 'MSA와 5G 네트워크'

❖ In a DevOps model uses a process of continuous development, test, and deployment.

네트워크 자동화를 통해 업그레이드 작업 간소화

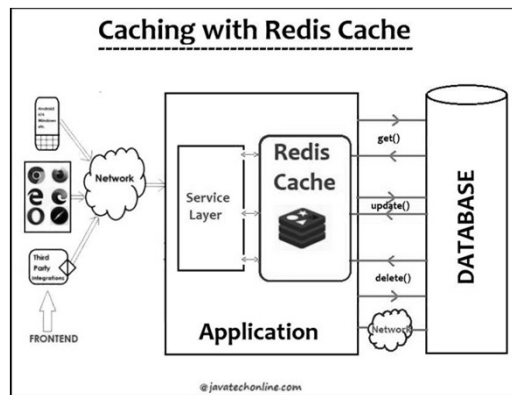


Source: GitLab
Source: <https://www.5gtechnologyworld.com/network-automation-takes-the-work-out-of-upgrades/>

I. 'MSA와 5G 네트워크'

❖ Redis Cache In Spring Boot Application

- Redis is an open source (BSD licensed) in-memory remote data structure store (database) that offers high performance, replication, and a unique data model.

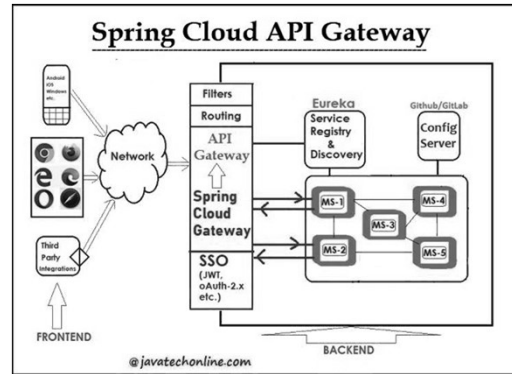


참고 Slide 361
Source: https://javatechonline.com/how-to-implement-redis-cache-in-spring-boot-application/?fbclid=IwAR0utgT8_uRbZAmHqS6pn3MnO9PxyXTVf5feNKJArOEe9j4i0JWJX-QyGew

I. 'MSA와 5G 네트워크'

❖ Spring Cloud Gateway In Microservices

- Spring Cloud Gateway is a starter project provided by Spring Cloud. It provides an API Gateway built on top of the Spring Ecosystem, including: Spring 5.x, Spring Boot 2.x, Spring WebFlux and Project Reactor. Spring Cloud Gateway targets to offer a simple, yet effective way to route to APIs and provide cross cutting concerns to them such as: security, monitoring/metrics, and resiliency..



Source: https://javatechonline.com/how-to-implement-redis-cache-in-spring-boot-application/?fbclid=IwAR0utgT8_uRbZAmHqS6pn3MnO9PxyXTVf5feNKJArOeE9j4i0JWJX-QyGew



I. 'MSA와 5G 네트워크'

❖ The Status of Open Source for 5G

5G Network Area	Focus	Brief Description	Open Source Effort References
Infrastructure	Hardware	High performance at lower cost by programmability and specialization of tasks	Open Compute Project: https://www.opencompute.org P4: https://p4.org
Infrastructure	Networking	Fast rate packet processing by acceleration techniques	DPDK: http://dpdk.org VPP: https://fd.io
Infrastructure	Operating System	Enabling white box use in carrier grade networks	Linux: https://www.linuxfoundation.org/projects/linux/ Berkle Software Distribution: http://www.bsd.org Disaggregated Network Operating System: https://www.danosproject.org
Access Network	Radio	Implementing 4G LTE and 5G Radio Access Network for NodeB and/or User Equipment	openair5G: https://gitlab.eurecom.fr/oai/openairinterface5g/wikis/home O-RAN: https://www.o-ran.org/
Core Network	Wireless Core Network	Implementing 4G LTE EPC and 5G NGC	openairCN: https://gitlab.eurecom.fr/oai/openairinterface5g/wikis/home M-CORD NGIC: https://software.intel.com/en-us/articles/an-interactive-demo-of-the-next-generation-infrastructure-core-reference-implementation
Management & Control	Networking	Carrier grade packet processing and flow control	OpenDaylight: https://www.opendaylight.org ONOS: https://onosproject.org Open vSwitch: https://www.openvswitch.org M-CORD NGIC: https://software.intel.com/en-us/articles/an-interactive-demo-of-the-next-generation-infrastructure-core-reference-implementation FD.io: https://fd.io
Management & Control	Virtualization	Abstraction of general compute resources to be shared across multiple applications and logical networks	OpenStack: https://www.openstack.org Kubernetes: https://kubernetes.io Docker: https://www.docker.com
Management & Control	Orchestration	Frameworks for describing dynamic function and network deployment policies with specific performance characteristics	Open Source MANO (OSM): https://osm.etsi.org MEF Lifecycle Service Orchestration (LSO): XOS: https://www.opennetworking.org/xos/

Source: 5G Americas



I. 'MSA와 5G 네트워크'

❖ The Status of Open Source for 5G

5G Network Area	Focus	Brief Description	Open Source Effort References
Management & Control	Automation	Frameworks and middleware for enabling Orchestration and Management tools to configure general compute and networking components via virtualization layers	xRAN: http://www.xrان.org ONAP: https://www.onap.org Ansible: https://www.ansible.com Terraform: https://www.terraform.io/
Management & Control	Modeling	Modeling tools and languages for defining function and network services for deployment used by Orchestration Frameworks	TOSCA: https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=tosca Juliu: http://jujucharms.com YAML: http://yaml.org YANG: https://tools.ietf.org/html/rfc6020
Management & Control	DevOps	Software development methods to automate process of building, validating and deploying workloads into NFV environments for service agility	Elasticsearch, Logstash, Kibana (ELK): https://www.elastic.co/elk-stack Consul: https://www.consul.io Etcd: https://coreos.com/etcd/ Jenkins: https://jenkins.io/ Puppet: https://puppet.com Chef: https://www.chef.io/chef/
Management & Control	Testing Tools		
Management & Control	Analytics	Data streaming protocols for continuous analysis of the service monitoring	Apache Kafka: https://kafka.apache.org/ Apache Spark: https://spark.apache.org/
Management & Control	AI	Framework for use of AI in Network	Automation https://www.acumos.org/
Management & Control	Edge Compute	Open source software for Edge	Computing https://www.akraino.org/
Management & Control	Cybersecurity	Security framework for Virtual network infrastructures	SHIELD: https://torsec.github.io/shield-h2020/about/summary.html

Source: 5G Americas



II. '가상화 (Virtualization) 인프라'

- 네트워크 가상화
- RAN 가상화
- SDN (Software Defined Networking)
- MEC와 하드웨어 가속

II. '가상화 (VIRTUALIZATION) 인프라'

95

❖ Virtualization is a key Step in Achieving 5G @ "5G 101: Guide for Getting Started"

- Software-defined networking (SDN) and network functions virtualization (NFV) are going to play a key role for operators as they prepare to migrate from LTE to 5G and scale their networks quickly. SDN will be necessary for operators to carve virtual "sub-networks" or slices that can be then used for bigger bandwidth applications. That includes video, which is projected to be 82% of all IP traffic by 2022 with use cases like video conferencing or streaming 4K video, which can use between 15 to 25 Mb/s. Lower bandwidth devices, such as smartwatches, will also be part of a sub-network connecting devices that are less demanding on the network

sdxcntral

Source: <https://www.sdxcntral.com/5g/guides/5g-101-guide/>



JS Lab

95

II. '가상화 (VIRTUALIZATION) 인프라'

96

❖ 네트워크 가상화, -假想化, Network Virtualization

- 하나의 물리적 네트워크가 마치 여러 개의 다른 기종 프로토콜이 운영되는 논리적 오버레이 네트워크로 운용되는 것을 가리키는 말. 클라우드 컴퓨팅과 미래 인터넷에서 핵심기술로 대두되고 있다. 인터넷에서 요구하는 가상화 기술에는 호스트 가상화, 링크 가상화, 라우터 가상화, 스위치 가상화 등이 있다.



Source: <http://terms.tta.or.kr/dictionary/dictionaryView.do?subject=%EB%84%A4%ED%8A%B8%EC%9B%8C%ED%81%AC+%EA%B0%80%EC%83%81%ED%99%94>



JS Lab

96

II. '가상화 (VIRTUALIZATION) 인프라'

97

❖ 네트워크 가상화

- 네트워크 가상화는 물리적인 네트워크를 하나 이상의 논리적 네트워크로 세분화하는 것을 의미하며, 네트워크 인프라에 대한 투자 대비 네트워크 인프라 자원 활용의 극대화를 목표로 한다. 해당 산업은 스마트폰, 노트북, 태블릿 등의 수요 증가, 클라우드 서비스 급증, 수십 GB 크기의 비디오 영상 제공 등 외부 환경 요인에 영향을 받고 있으며 기존 네트워크 구조의 문제점을 해결하며, 미래의 네트워크 환경(IoT, 5G)을 대비할 수 있는 산업으로 주목받고 있다. 하나의 물리적 네트워크 장비에서 다수의 가상네트워크 인터페이스 기능을 지원해주는 링크 가상화, 하나의 물리적인 라우터에서 자원을 분리하여 다수의 가상 라우터를 구성하는 라우터 가상화 등이 포함된다. 최근 모바일, 태블릿 등 사용량 및 클라우드 서비스의 증가, 데이터 전송량 증가에 따라 소프트웨어 정의 네트워크(Software Defined Network, SDN)와 네트워크 기술 가상화(Network Function Virtualization, NFV)가 네트워크 가상화의 핵심기술로 조명되고 있다.

• 등장배경:

- ✓ 모빌리티 수요 증가
- ✓ 클라우드 서비스 급증
- ✓ 트래픽 패턴의 변화
- ✓ 새로운 네트워크 아키텍처에 대한 수요

Source: 네트워크 가상화 - 해시넷 (hash.kr)

JS Lab

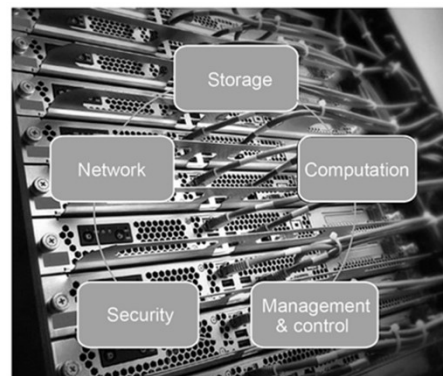
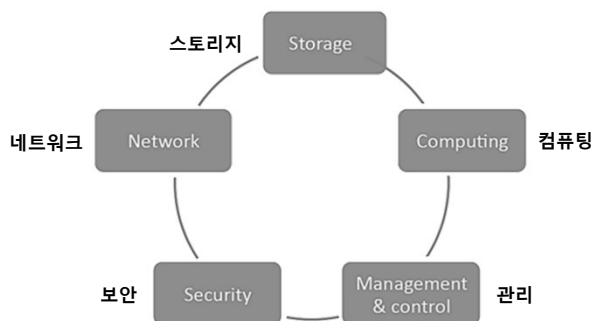
97

II. '가상화 (VIRTUALIZATION) 인프라'

98

❖ 가상화 기반 SDN의 확장

- The five domains necessary for the life of a company
- Virtualization of the five domains



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

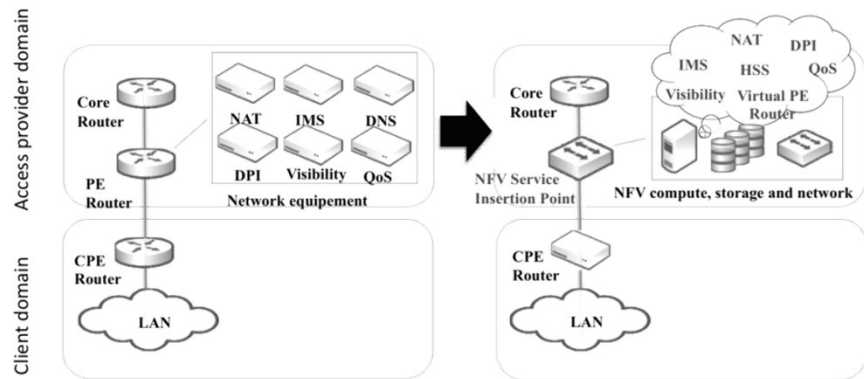
98

II. '가상화 (VIRTUALIZATION) 인프라'

99

❖ 코어 네트워크의 가상화

- Virtualization of a core network



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

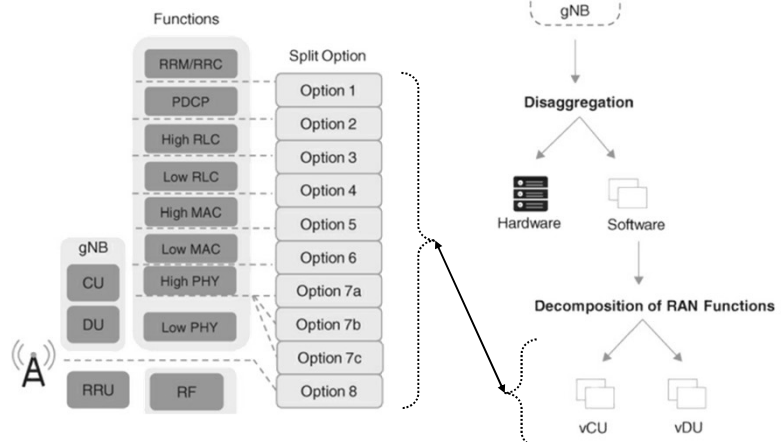
99

II. '가상화 (VIRTUALIZATION) 인프라'

100

❖ Disaggregation and Decomposition of gNB

❖ Functional Split Options in 5G RAN



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

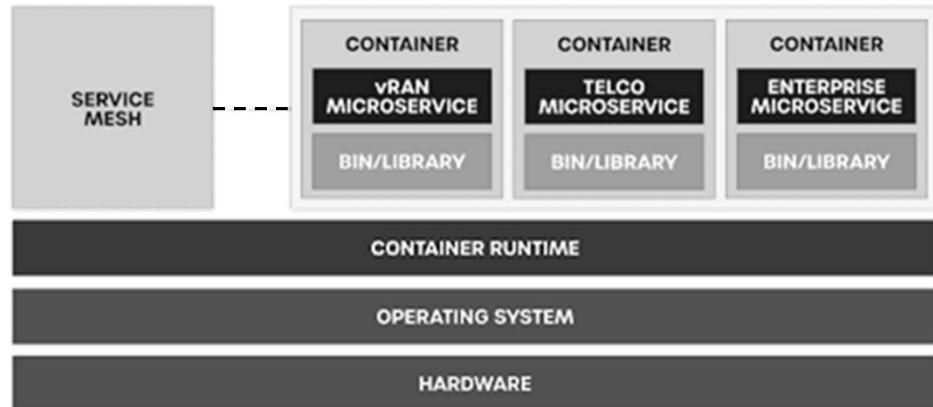
JS Lab

100

II. '가상화 (VIRTUALIZATION) 인프라'

101

❖ Basics of cloud-native virtual and Open RAN architecture



RCRWirelessNews

source: <https://www.rcwireless.com/20210830/5g/how-to-secure-cloud-native-5g-virtual-and-open-ran-infrastructure>

JS Lab

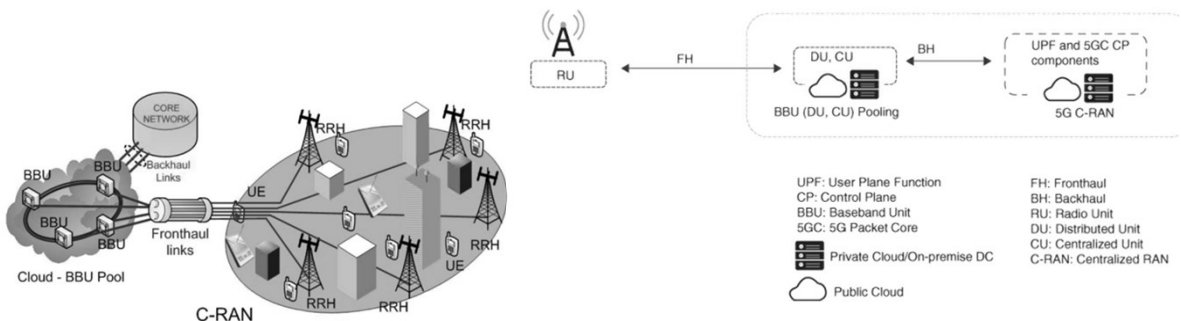
101

II. '가상화 (VIRTUALIZATION) 인프라'

102

❖ 5G 환경의 RAN 가상화 응용

- Cloud-RAN (C-RAN): a 5G-type vRAN / O-RAN Deployment Options



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

JS Lab

102

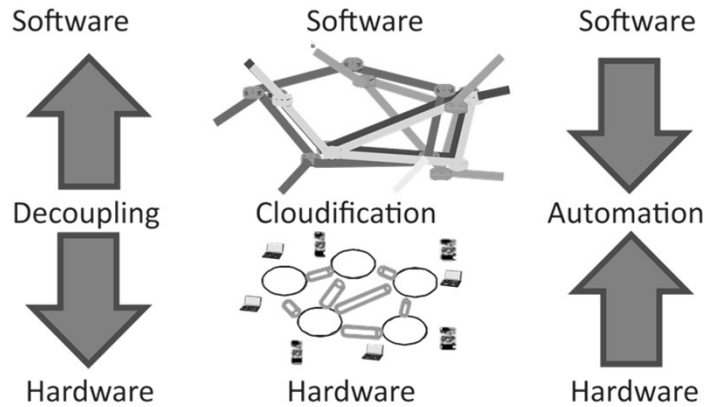
II. '가상화 (VIRTUALIZATION) 인프라'

103

❖ 가상화와 SDN

• The three basic principles

- 분리 (Decoupling)
- 클라우드화 (Cloudification)
- 자동화 (Automation)



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

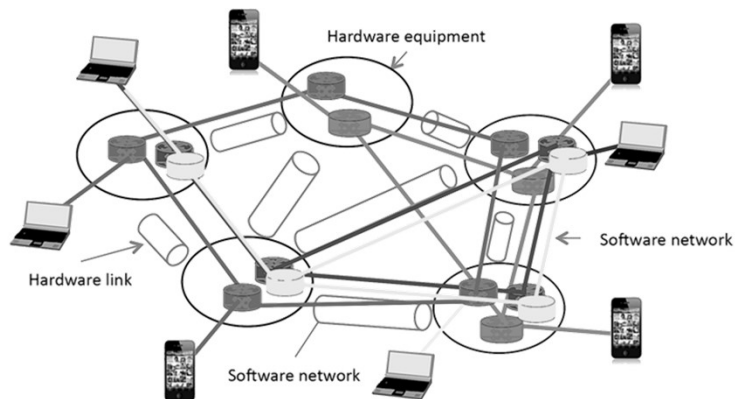
103

II. '가상화 (VIRTUALIZATION) 인프라'

104

❖ 네트워크 가상화(Virtualization)

- A set of software networks.



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

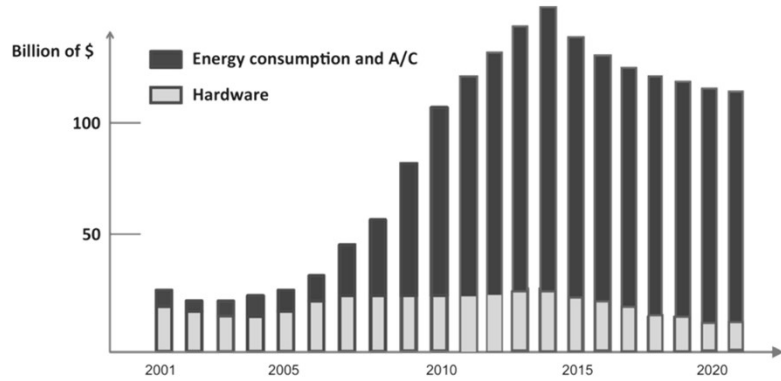
104

II. '가상화 (VIRTUALIZATION) 인프라'

105

❖ SDN의 비용 절감

- The cost of a datacenter environment



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

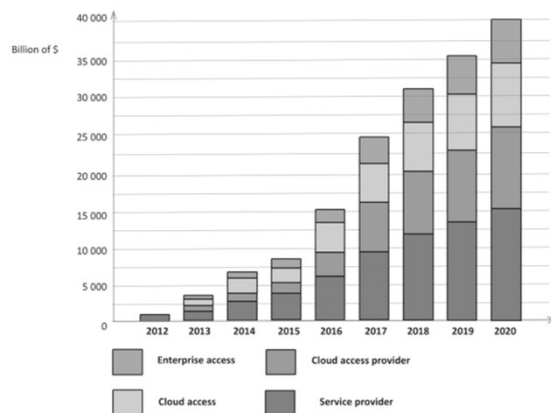
105

II. '가상화 (VIRTUALIZATION) 인프라'

106

❖ SDN의 시장 확대

- OpenFlow market, and more generally SDN market.



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

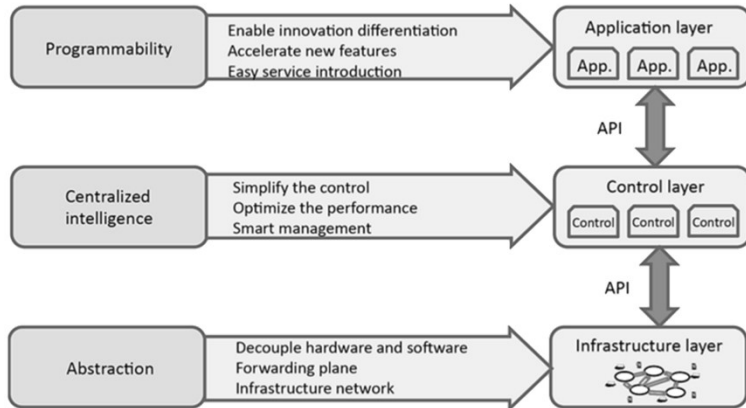
106

II. '가상화 (VIRTUALIZATION) 인프라'

107

❖ SDN

- The ONF architecture



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

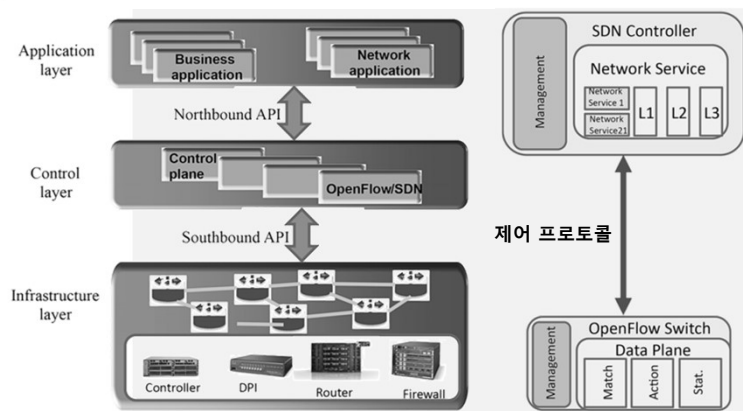
107

II. '가상화 (VIRTUALIZATION) 인프라'

108

❖ SDN

- 제어 프로토콜 (The signaling protocol OpenFlow)
- The control layer and its interfaces



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

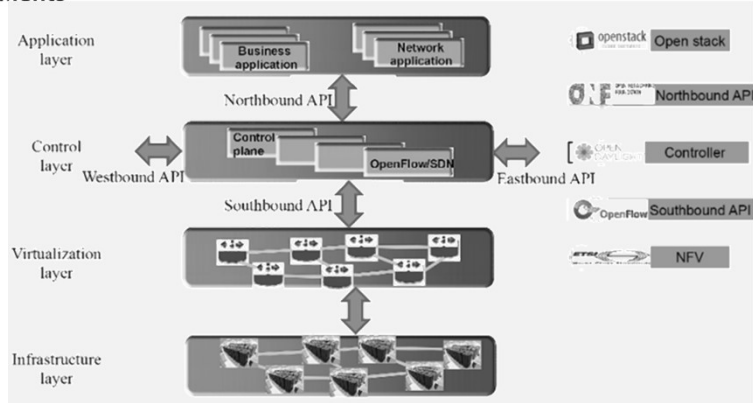
108

II. '가상화 (VIRTUALIZATION) 인프라'

109

❖ SDN

- 가상화 계층 (Virtualization Layer)
- Example of open source developments



Source: <https://opennetworking.org/news-and-events/blog/onf-facebook-and-radisys-make-strides-participating-in-o-ran-alliance-global-plugfest/>
Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

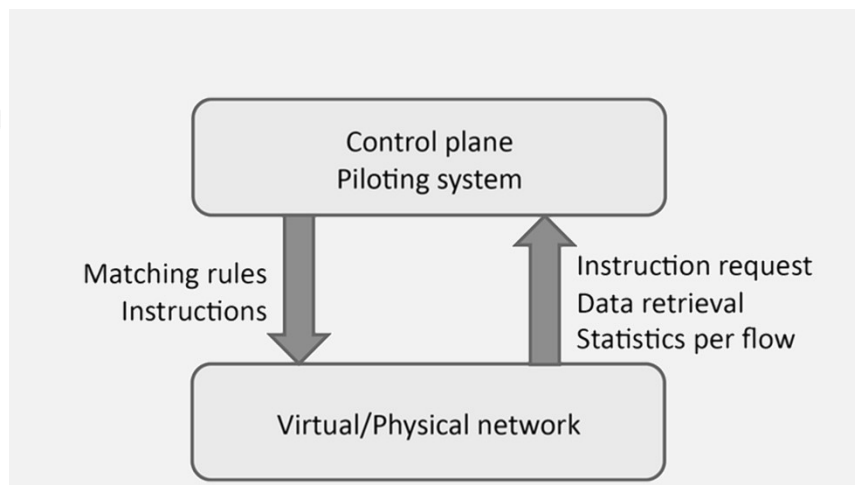
109

II. '가상화 (VIRTUALIZATION) 인프라'

110

❖ SDN App 서비스 (예)

- Distributed Switching
- Distributed Routing
- Distributed Firewall
- The load balancing protocol



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

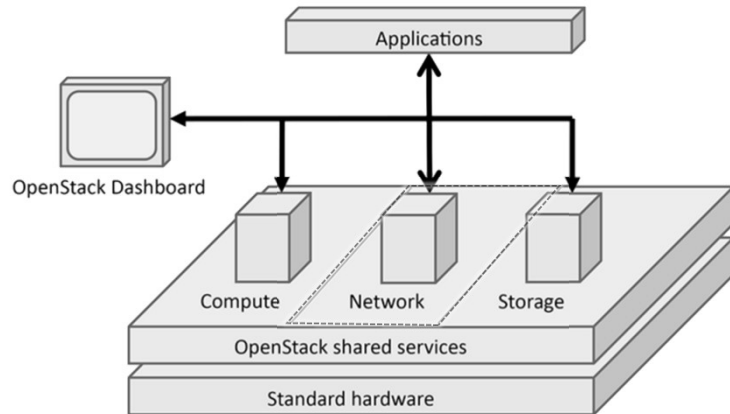
110

II. '가상화 (VIRTUALIZATION) 인프라'

111

❖ 오픈스택의 SDN 기능 제공

- Network @ the OpenStack system



'OpenStack' : Slide 357, Slide 359
Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

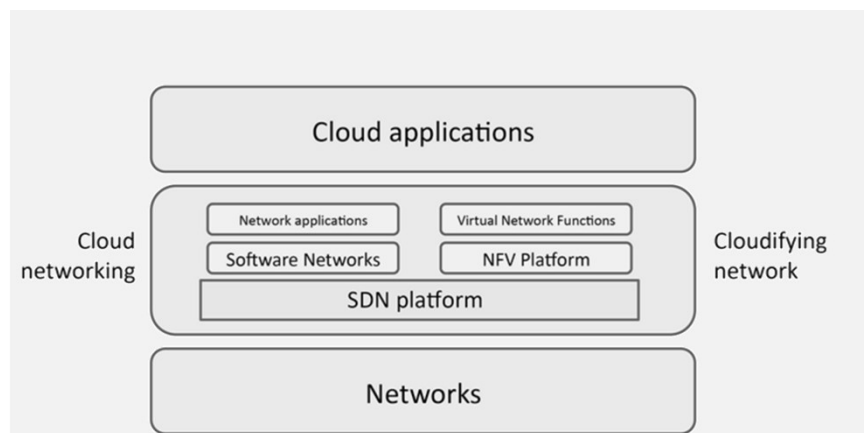
111

II. '가상화 (VIRTUALIZATION) 인프라'

112

❖ 클라우드 네트워킹의 SDN 구조

- The overall architecture of SDN solutions



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

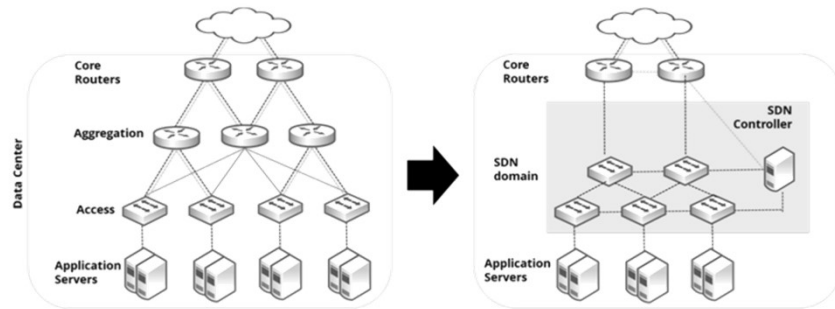
112

II. '가상화 (VIRTUALIZATION) 인프라'

113

❖ Fabric, SD-WAN, vCPE, vRAN, vEPC

- Old and new generation fabric architecture



JS Lab

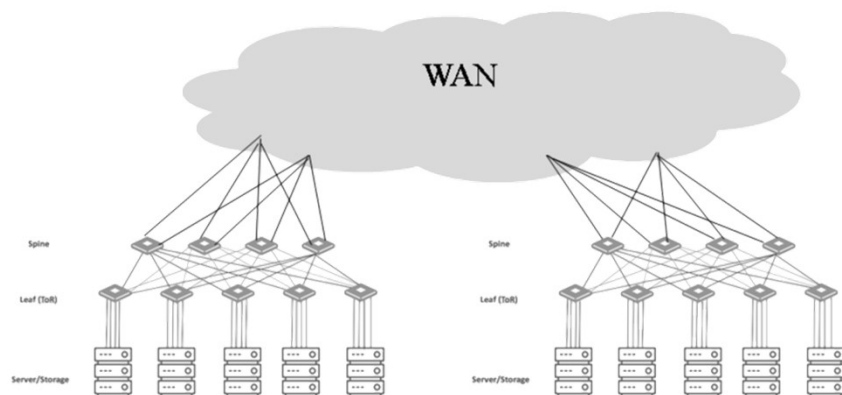
113

II. '가상화 (VIRTUALIZATION) 인프라'

114

❖ Fabric, SD-WAN, vCPE, vRAN, vEPC

- Fabrics interconnection



JS Lab

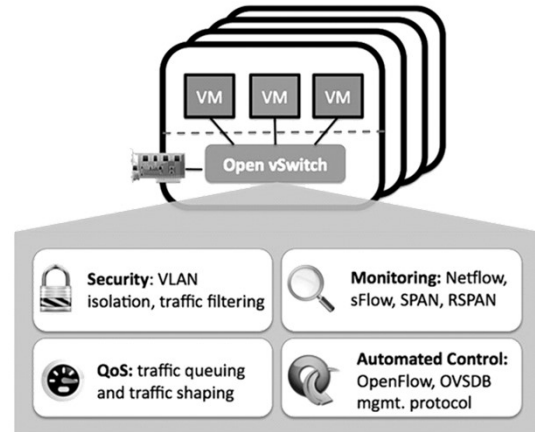
114

II. '가상화 (VIRTUALIZATION) 인프라'

115

❖ The characteristics of Open vSwitch

- 멀티 클라우드 연계를 위한 표준 역할



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

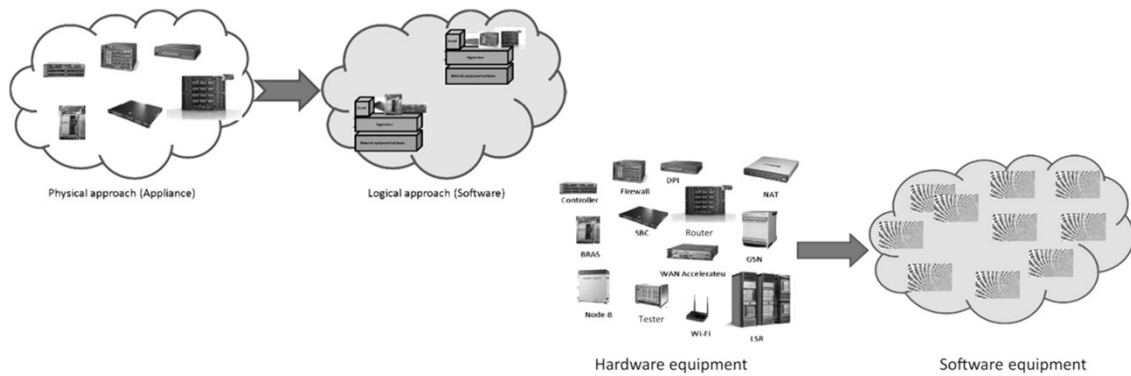
115

II. '가상화 (VIRTUALIZATION) 인프라'

116

❖ SDN의 NFV연계

- NFV (Network Functions Virtualization)



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

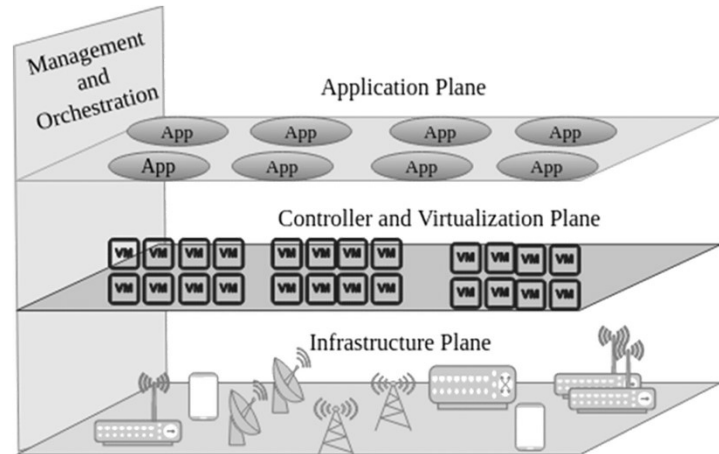
JS Lab

116

II. '가상화 (VIRTUALIZATION) 인프라'

117

- ❖ SDN/NFV 통합 아키텍처: A unified architecture for SDN and NFV



Source: https://www.researchgate.net/figure/A-unified-architecture-for-SDN-and-NFV_fig1_355473965

JS Lab

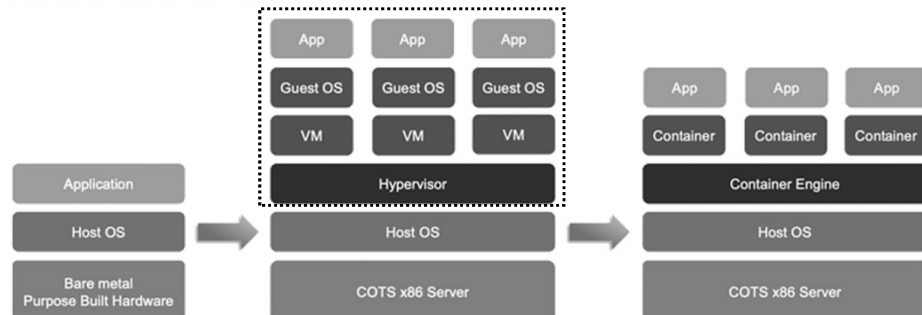
117

II. '가상화 (VIRTUALIZATION) 인프라'

118

- ❖ 가상화의 진화 (Evolution of Virtualization): Network automation uses zero-touch positioning, Continuous Integration/Continuous Development, and AI/ML to bring upgrades to the radio access network.

EVOLUTION OF VIRTUALIZATION



Source: Parallel Wireless.

Source: <https://www.5gtechnologyworld.com/network-automation-takes-the-work-out-of-upgrades/>

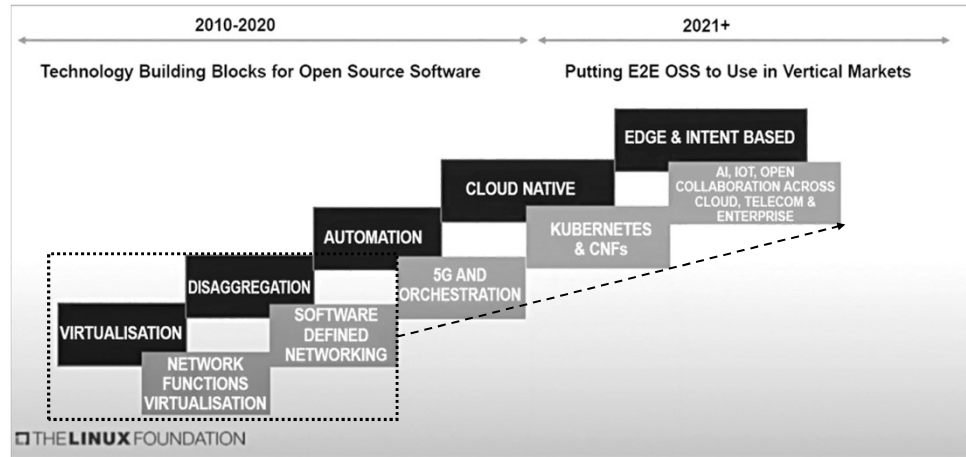
JS Lab

118

II. '가상화 (VIRTUALIZATION) 인프라'

119

❖ LF edge projects (Linux Foundation)



Source: <https://www.electronicsforu.com/technology-trends/open-source-ecosystem-5g-telecom-networks>



JS Lab

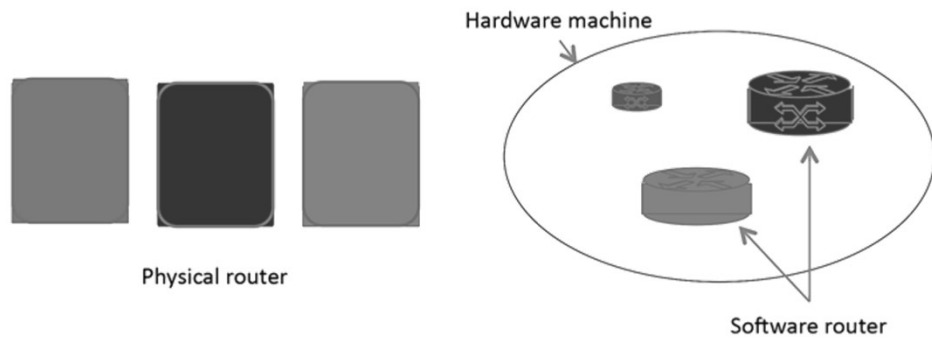
119

II. '가상화 (VIRTUALIZATION) 인프라'

120

❖ Virtualization

- Virtualization of three routers.



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

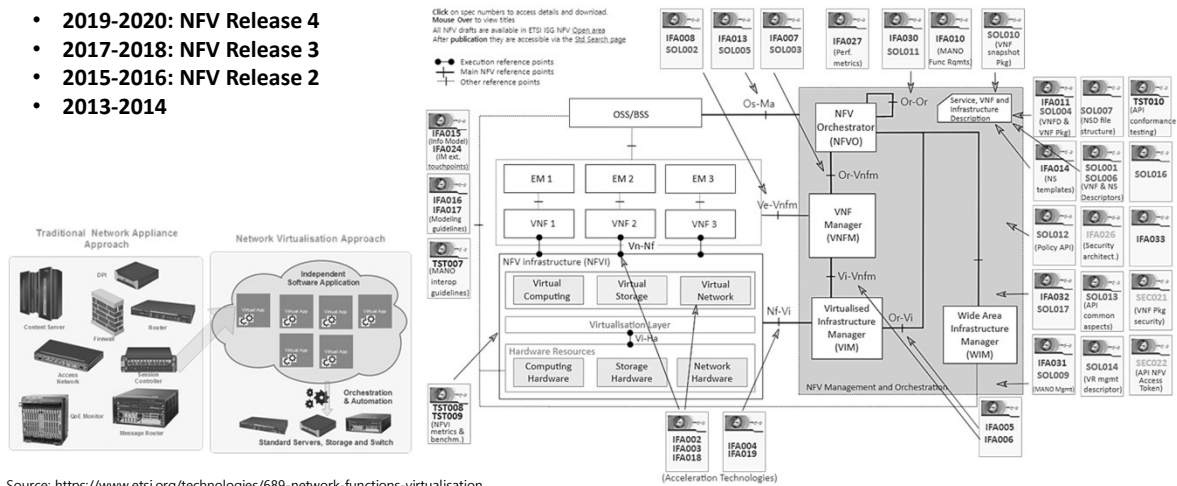
120

II. '가상화 (VIRTUALIZATION) 인프라'

121

❖ NFV - Network Functions Virtualisation (ETSI – Standards), 2012년

- 2019-2020: NFV Release 4
- 2017-2018: NFV Release 3
- 2015-2016: NFV Release 2
- 2013-2014



Source: <https://www.etsi.org/technologies/689-network-functions-virtualisation>

JS Lab

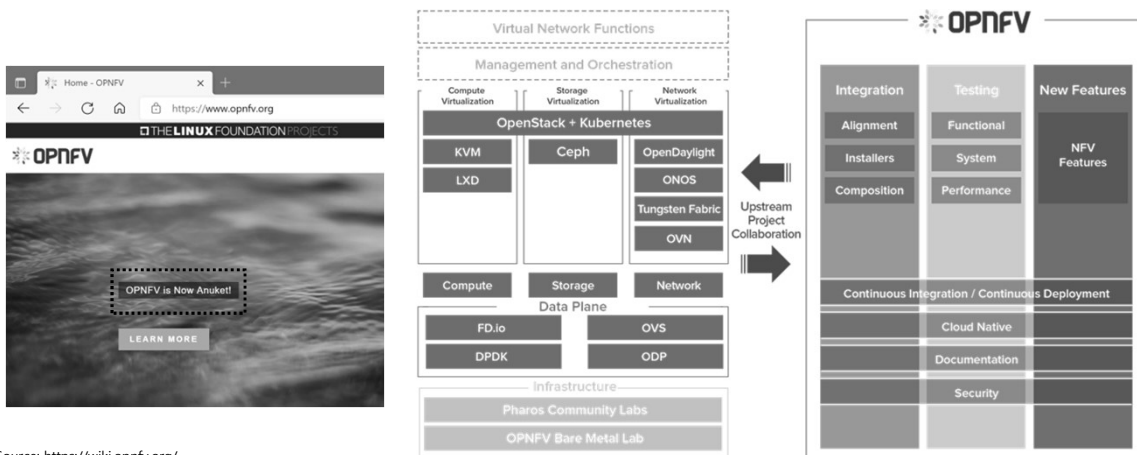
121

II. '가상화 (VIRTUALIZATION) 인프라'

122

❖ OPNFV - Open Platform for NFV (2014년~2021년)

- 2021년 Anuket 변경



Source: <https://wiki.opnfv.org/>

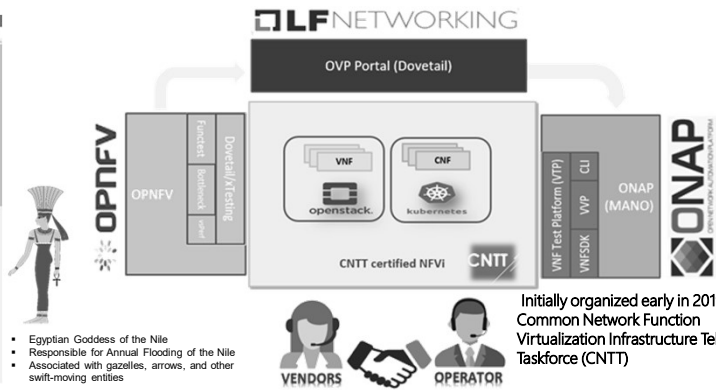
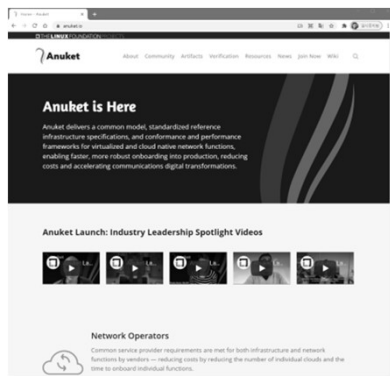
JS Lab

122

II. '가상화 (VIRTUALIZATION) 인프라'

123

❖ Anuket (=OPNFV+CNTT)



Source: <https://wiki.onap.org/display/DW/OVP+Introduction>

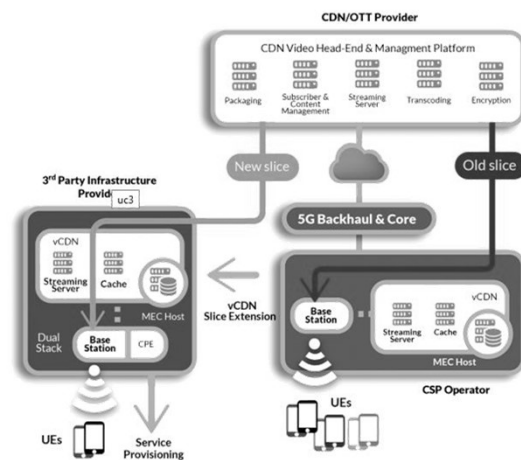
JS Lab

123

II. '가상화 (VIRTUALIZATION) 인프라'

124

❖ vCDN use-case with elastic MEC-enabled slices



Source: 5GPPP Architecture Working Group 5G Architecture - White Paper

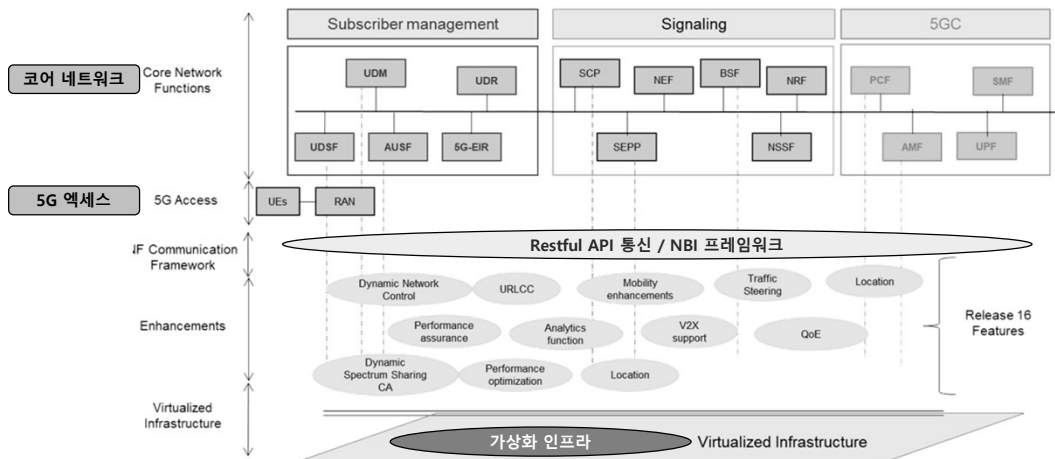
JS Lab

124

II. '가상화 (VIRTUALIZATION) 인프라'

125

❖ Release 16 5G features and enhancements supporting verticals



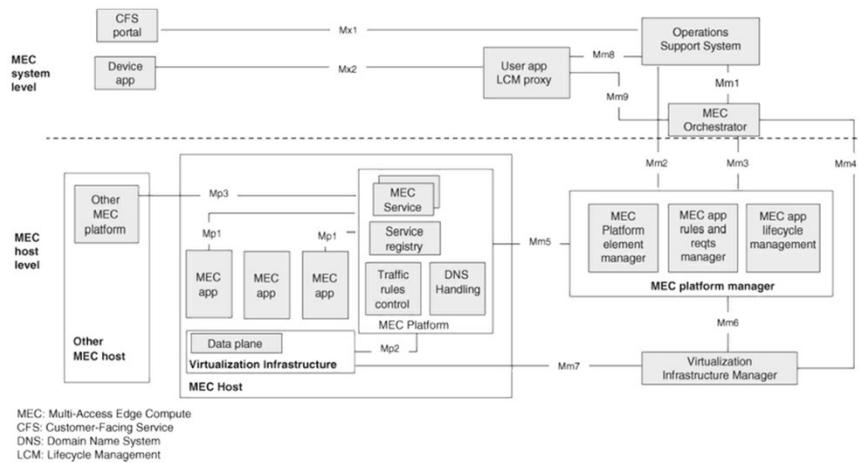
JS Lab

125

II. '가상화 (VIRTUALIZATION) 인프라'

126

❖ ETSI MEC Framework



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.



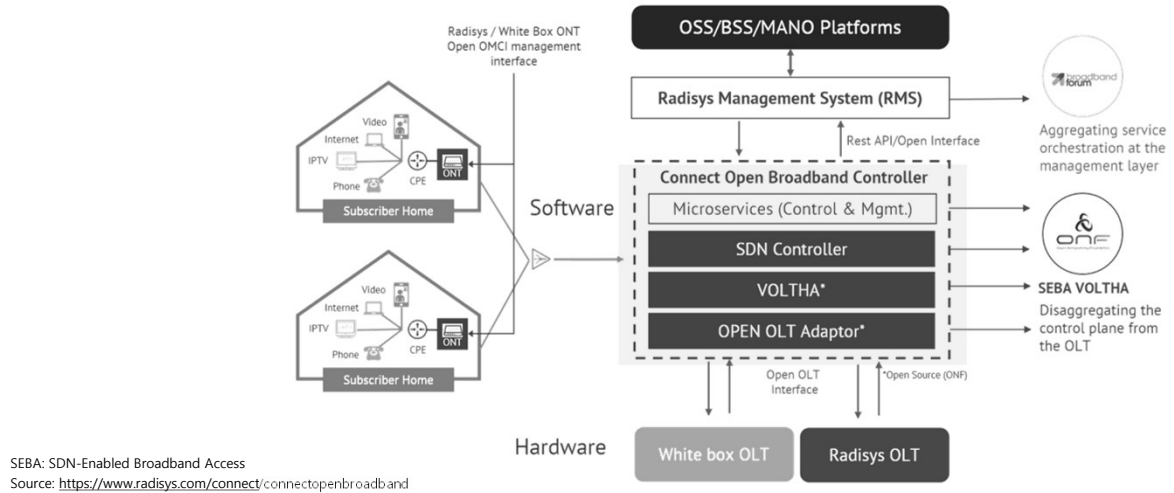
JS Lab

126

II. '가상화 (VIRTUALIZATION) 인프라'

127

- ❖ 제조사의 브로드밴드 오픈소스 (예): Radisys - Broadband access portfolio offering open source-based software



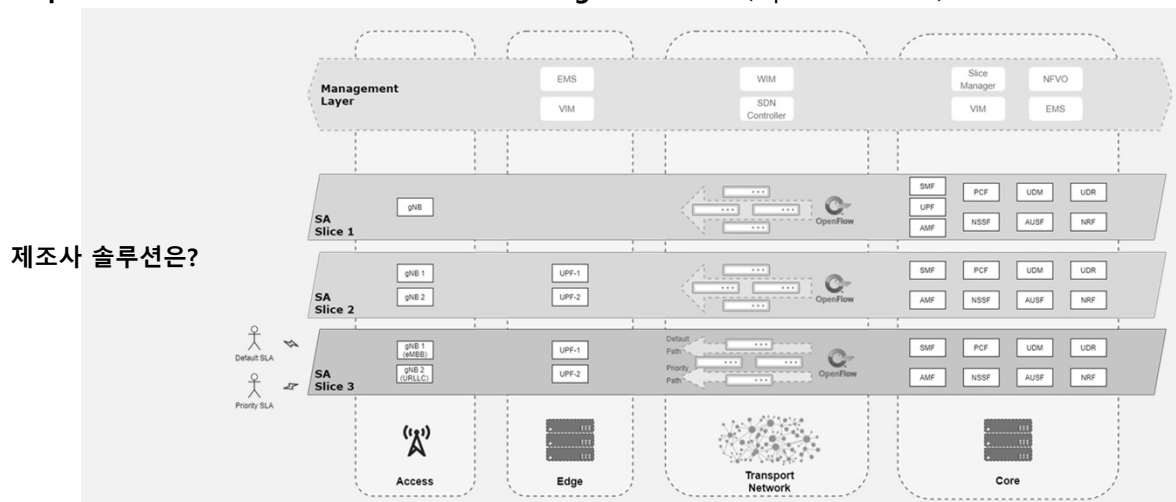
JS Lab

127

II. '가상화 (VIRTUALIZATION) 인프라'

128

- ❖ Open Source - 5G Network E2E Slice Manager – Katana (OpenFlow 사용)



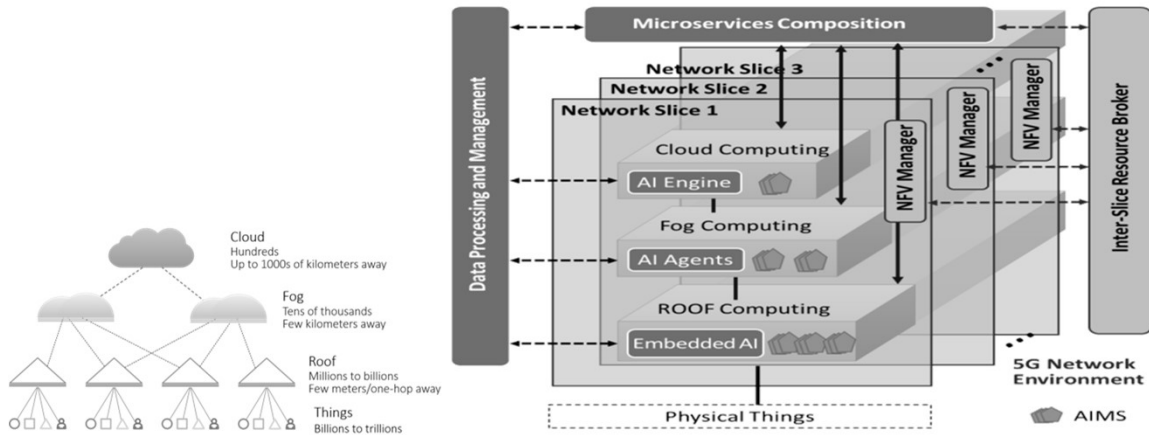
JS Lab

128

II. '가상화 (VIRTUALIZATION) 인프라'

129

- ❖ The ecosystem of microservices distributed across the ROOF-Fog-Cloud systems over 5G networks



Source: https://www.itu.int/en/ITU-T/academia/kaleidoscope/2018/Documents/Presentations/S2_2_AI%20as%20a%20Microservice_UM.pdf



JS Lab

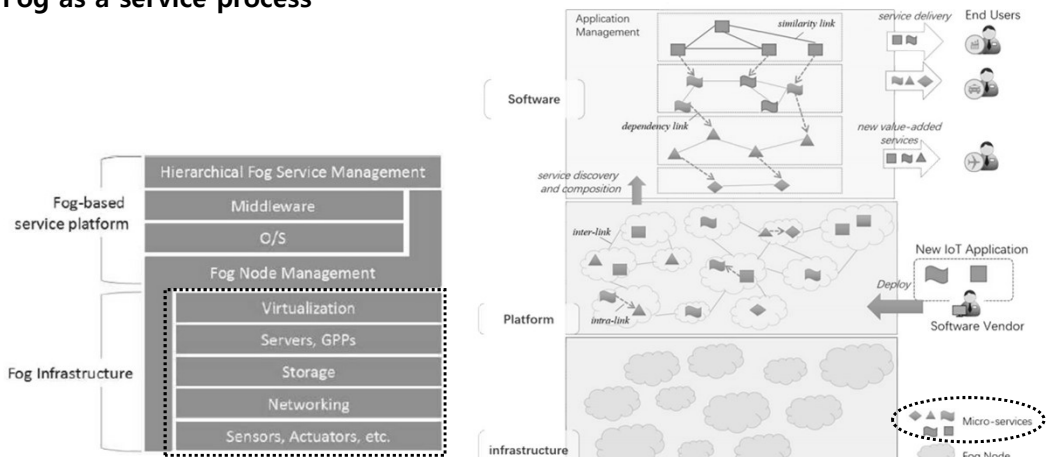
129

II. '가상화 (VIRTUALIZATION) 인프라'

130

- ❖ Mobile Microservices: Building Flexible Pervasive Applications

- Fog as a service process



Source: Chen, Nanxi. Mobile Microservices (p. 62). CRC Press. Kindle Edition.



JS Lab

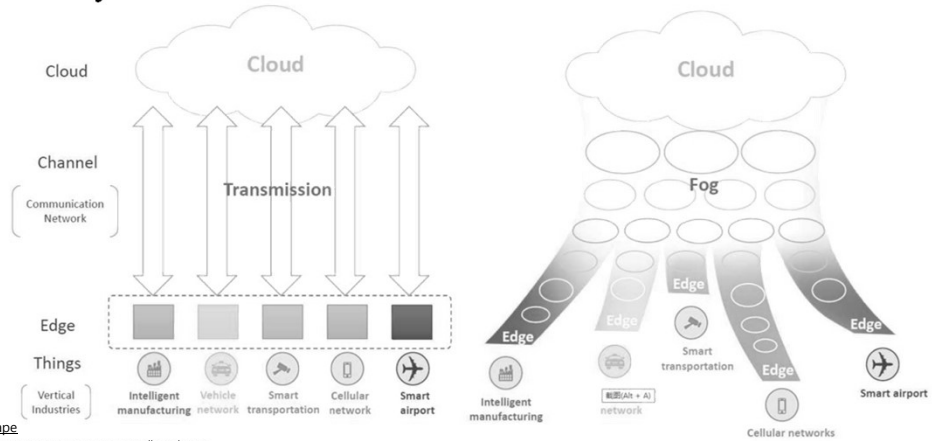
130

II. '가상화 (VIRTUALIZATION) 인프라'

131

❖ Microservices Deployment in Edge/Fog Computing Environments

- a. The Cloud-Edge-Things system
- b. the fog as a service system



AI Chip Landscape: 부록4. AI Chip Landscape
Source: Chen, Nanxi. Mobile Microservices (p. 59). CRC Press. Kindle Edition

JS Lab

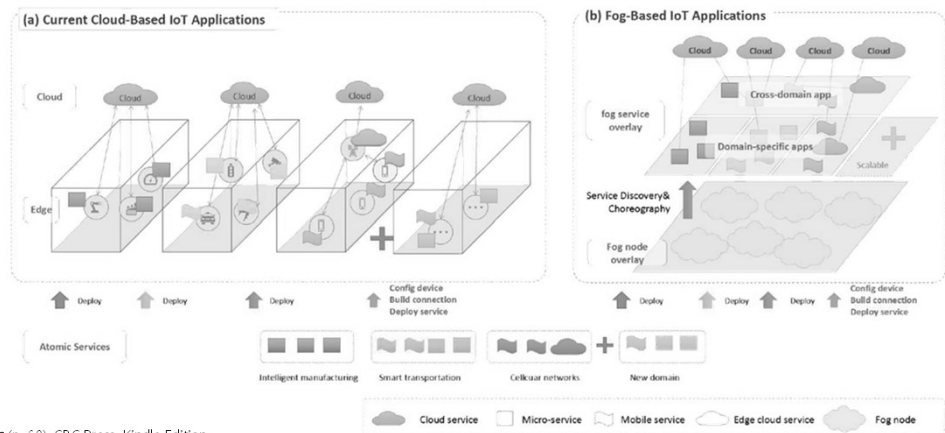
131

II. '가상화 (VIRTUALIZATION) 인프라'

132

❖ Mobile Microservices: Building Flexible Pervasive Applications

- a. Current cloud-based IoT application,
- b. Fog-based IoT application



Source: Chen, Nanxi. Mobile Microservices (p. 60). CRC Press. Kindle Edition.

JS Lab

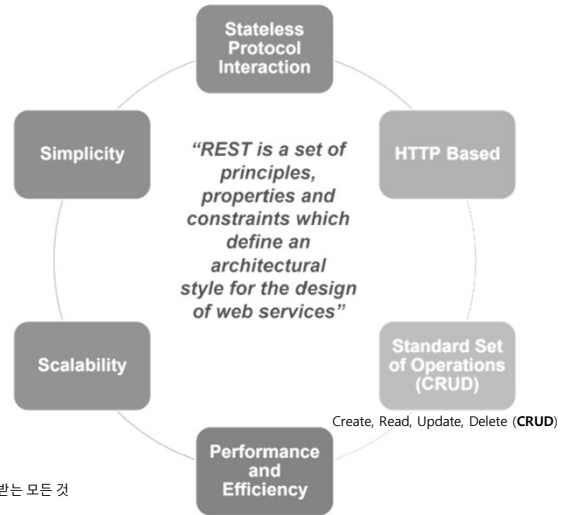
132

II. '가상화 (VIRTUALIZATION) 인프라'

133

❖ REST 가이드라인

- 단순성 (Simplicity)
- 확장성 (Scalability)
- 성능과 효율 (Performance and Efficiency)
- 운영의 표준 세트 (Standard Set of Operations)
- HTTP 기반 (HTTP based)
- 스테이트리스 프로토콜 상호작용 (Stateless)



REST(Representational State Transfer): 자원을 이름(자원의 표현)으로 구분하여 해당 자원의 상태(정보)를 주고 받는 모든 것
Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

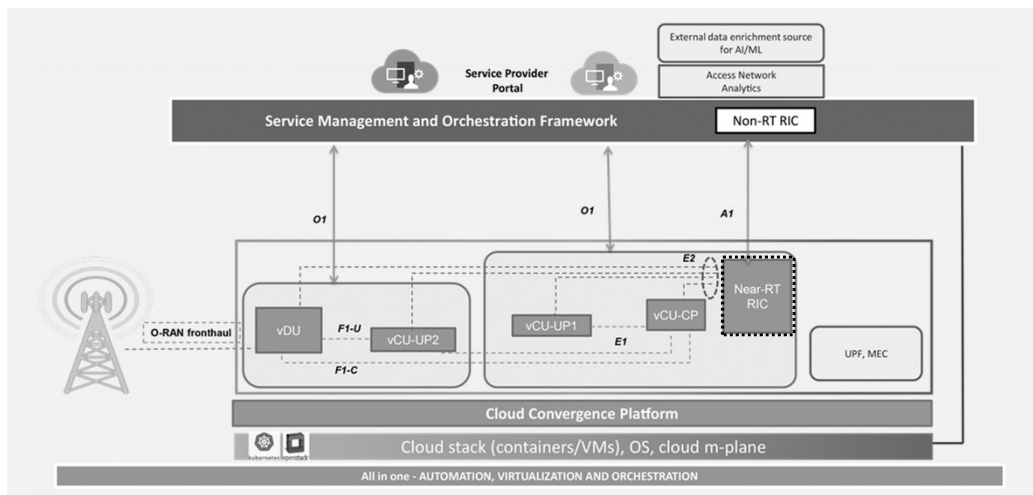
JS Lab

133

II. '가상화 (VIRTUALIZATION) 인프라'

134

❖ Open RAN network: Rakuten's 5G Cloud-Native Network



Source: <https://www.altiostar.com/altiostar-firmly-establishes-open-vran-leadership-with-the-launch-of-rakutens-5g-cloud-native-network/>

JS Lab

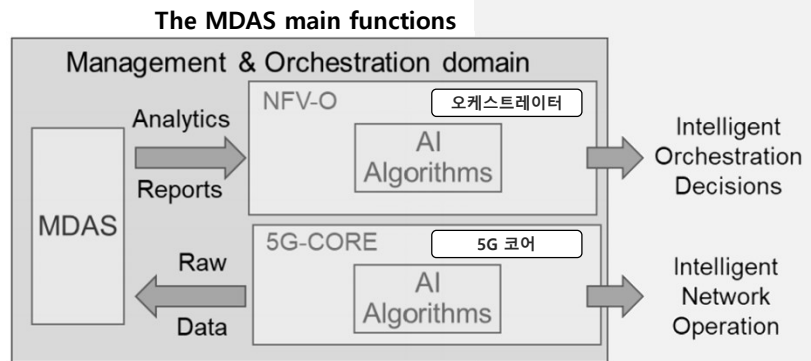
134

II. '가상화 (VIRTUALIZATION) 인프라'

135

❖ 가상화 관리의 AI 적용: Management analytics function

- Management Data Analytics Service (MDAS)



Source: AI and ML – Enablers for Beyond 5G Networks* (URL <http://doi.org/10.5281/zenodo.4299895>) , 5G PPP Technology Board, 2021-05-11

JS Lab

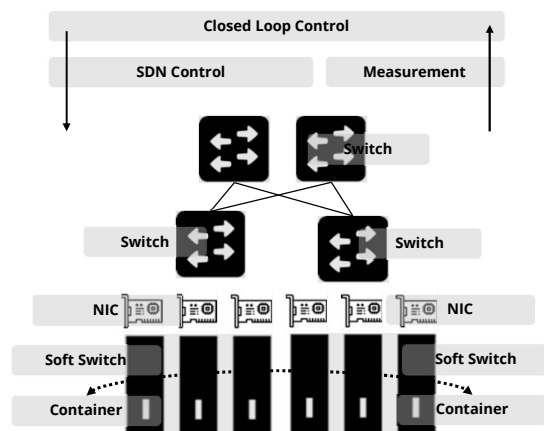
135

II. '가상화 (VIRTUALIZATION) 인프라'

136

❖ Needs of the New Datacenter

- Lines between servers and networking are blurring
- Developer optimized
- Needs to be cloud managed
- Need to consider traffic end-to-end
- Need to orchestrate all these components



ONF

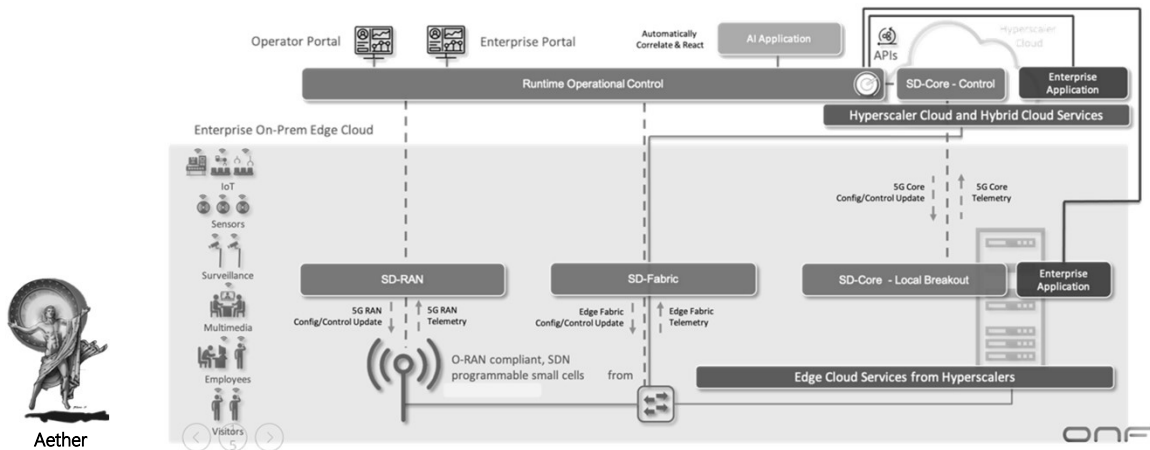
JS Lab

136

II. '가상화 (VIRTUALIZATION) 인프라'

137

❖ Aether: 엔터프라이즈의 DT을 위한 5G 커넥티드 에지 플랫폼 오픈소스



Source: <https://opennetworking.org/wp-content/uploads/2020/12/Spotlight-OPS-1.pdf>

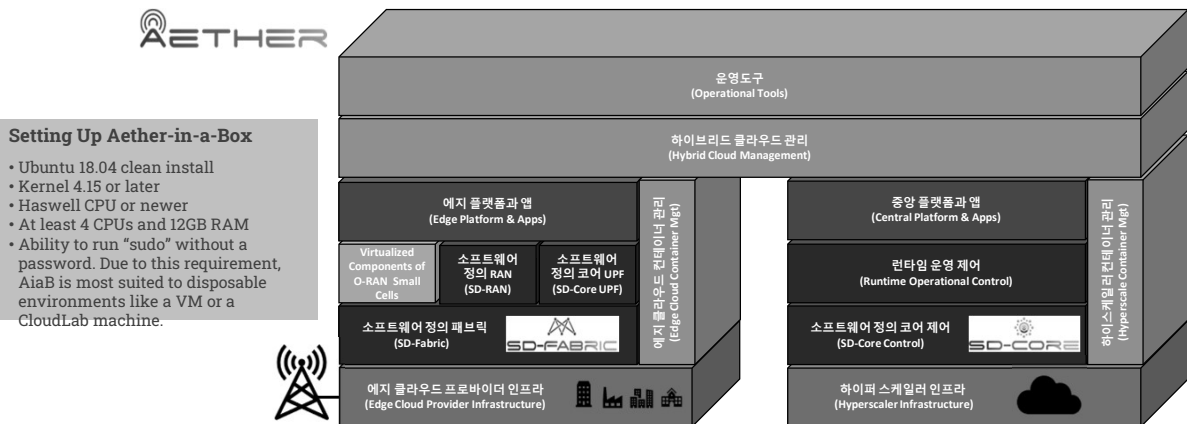
JS Lab

137

II. '가상화 (VIRTUALIZATION) 인프라'

138

❖ SD-Core and SD-Fabric are an Integral Part of Aether



Source: <https://docs.aetherproject.org/master/developer/aiaB.html>

JS Lab

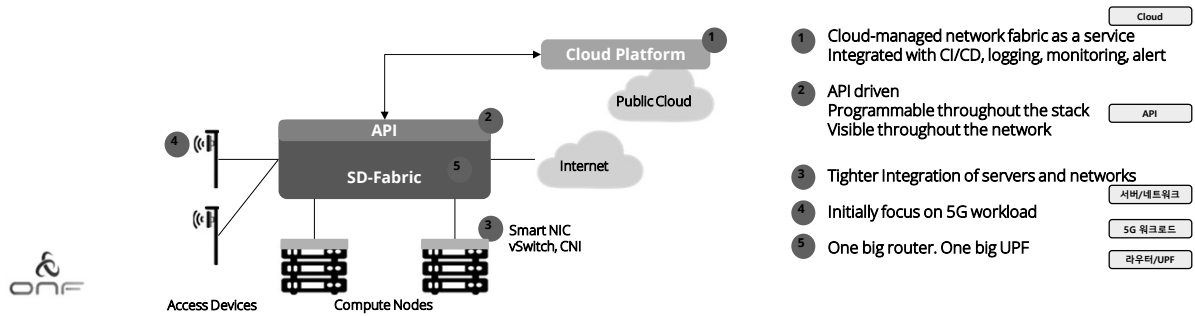
138

II. '가상화 (VIRTUALIZATION) 인프라'

139

❖ SD-Fabric Overview

- Control APIs
 - Network slicing and QoS management
 - Path selection (redirecting)
 - Access control (blocking)
- Telemetry APIs
 - Monitor queue, path, latency and packet drops



- 1 Cloud-managed network fabric as a service
Integrated with CI/CD, logging, monitoring, alert
- 2 API driven
Programmable throughout the stack
Visible throughout the network
- 3 Tighter Integration of servers and networks
- 4 Initially focus on 5G workload
- 5 One big router. One big UPF



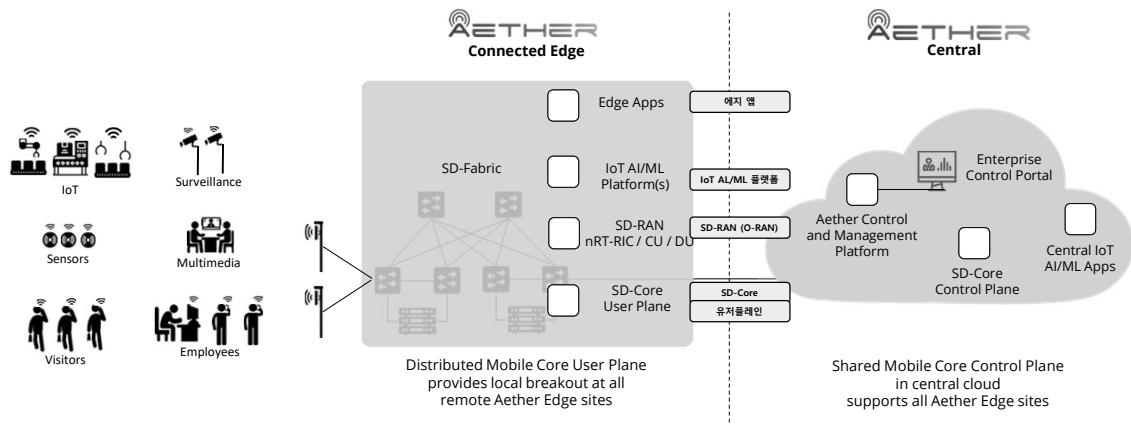
JS Lab

139

II. '가상화 (VIRTUALIZATION) 인프라'

140

❖ Aether: 5G/LTE Private Edge Cloud



Source: <https://opennetworking.org/sd-fabric/>

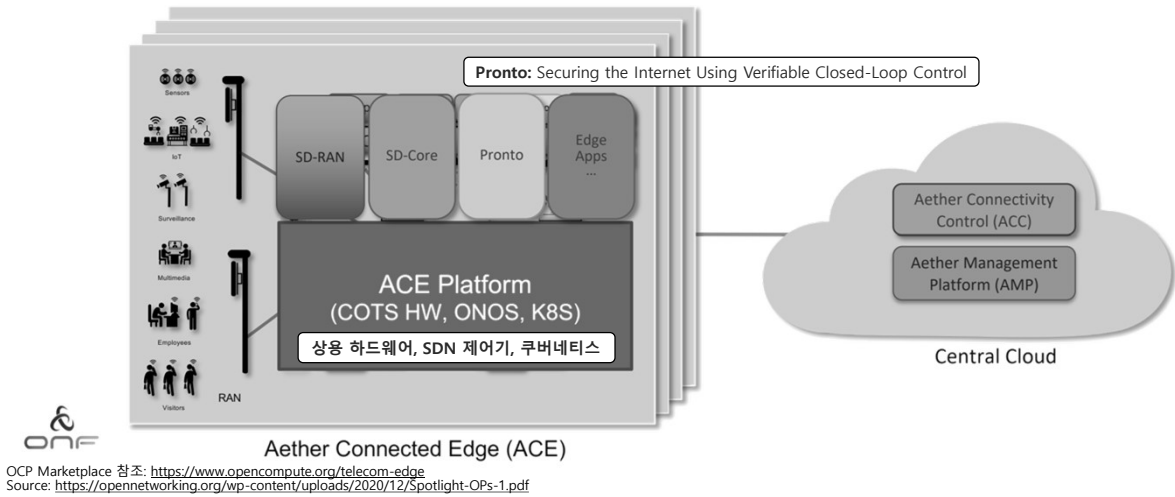
JS Lab

140

II. '가상화 (VIRTUALIZATION) 인프라'

141

❖ Aether: Components



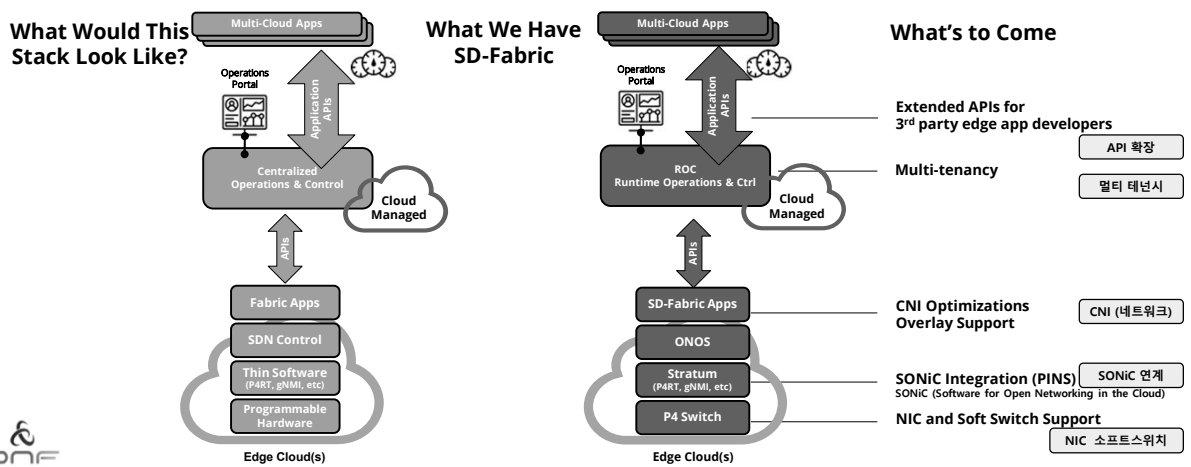
JS Lab

141

II. '가상화 (VIRTUALIZATION) 인프라'

142

❖ What's to Come



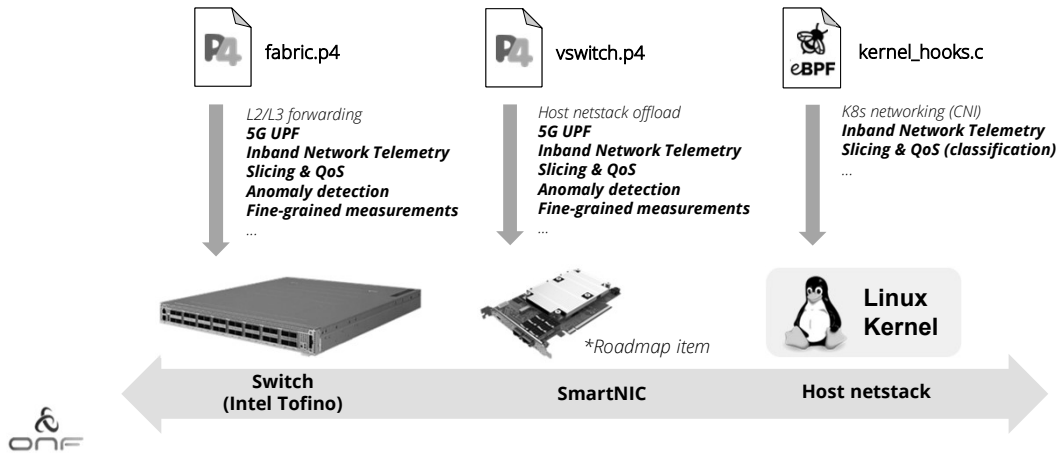
JS Lab

142

II. '가상화 (VIRTUALIZATION) 인프라'

143

❖ End-to-End Programmable Data Plane Control APIs



143

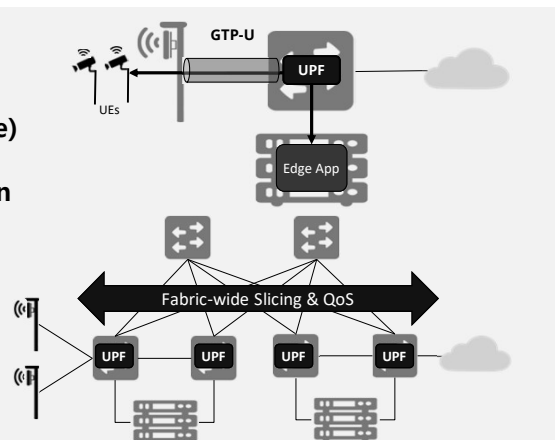
II. '가상화 (VIRTUALIZATION) 인프라'

144

❖ Embedded 5G UPF

- Free up CPU resources, run UPF at hardware speeds
 - Meet 5G requirements for ultra-low latency/jitter and high-throughput
- Tailored for enterprise and IoT use cases
 - GTP-U termination
 - Slicing & QoS
 - Usage reporting
 - Idle-mode buffering (cloud-native service)
- Distributed implementation
 - Any leaf can terminate any GTP-U session
 - Allows fabric-wide slicing and QoS
- INT visibility for SLA validation
 - Monitor flows inside GTP-U tunnels

상용 시장은?



144

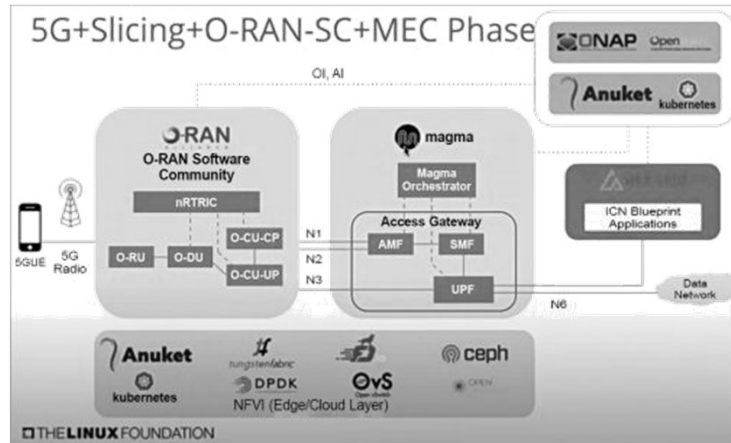
II. '가상화 (VIRTUALIZATION) 인프라'

145

❖ 5G modernization (Linux Foundation)

• three phases:

- 5G core+MEC phase,
- 5G E2E+MEC phase,
- 5G+Slicing+O-RAN-SC +MEC phase.



Source: <https://www.electronicshobby.com/technology-trends/open-source-ecosystem-5g-telecom-networks>

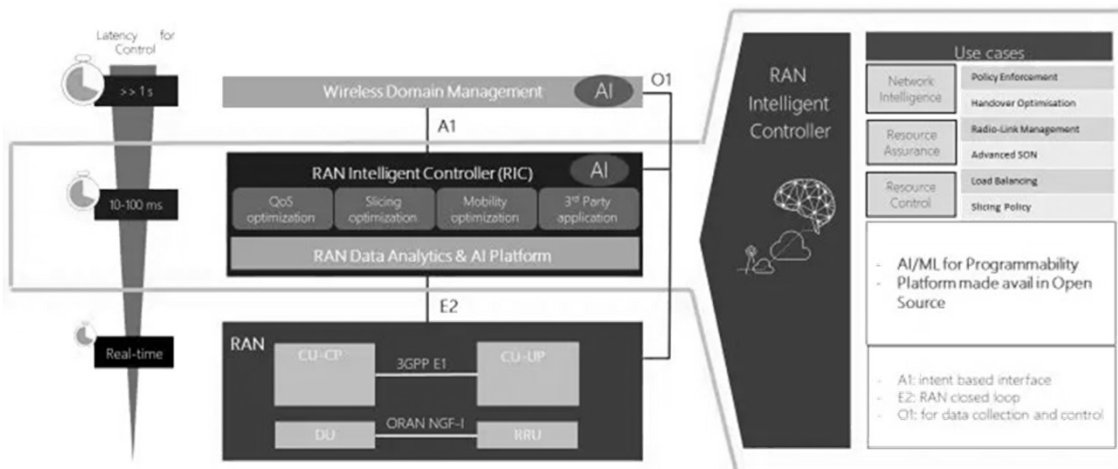
JS Lab

145

II. '가상화 (VIRTUALIZATION) 인프라'

146

❖ RAN Intelligent Controller by O-RAN (LF Networking)



Source: https://www.rcwireless.com/20201004/open_ran/5-open-ran-terms-to-know

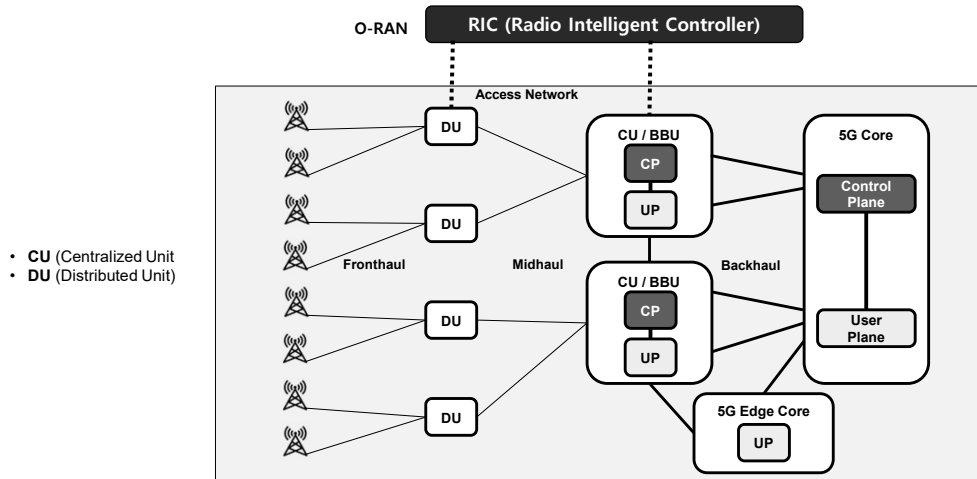
JS Lab

146

II. '가상화 (VIRTUALIZATION) 인프라'

147

❖ 가상화 기반 분리와 제어 5G Network Architecture (예)



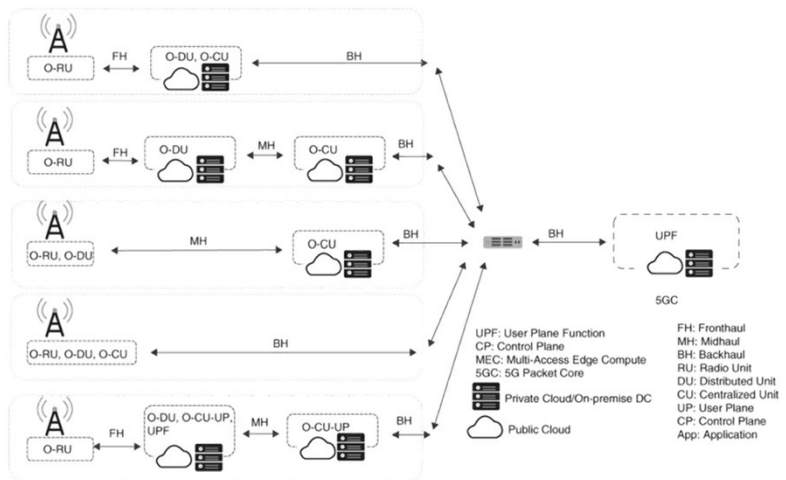
JS Lab

147

II. '가상화 (VIRTUALIZATION) 인프라'

148

❖ O-RAN Deployment Options



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

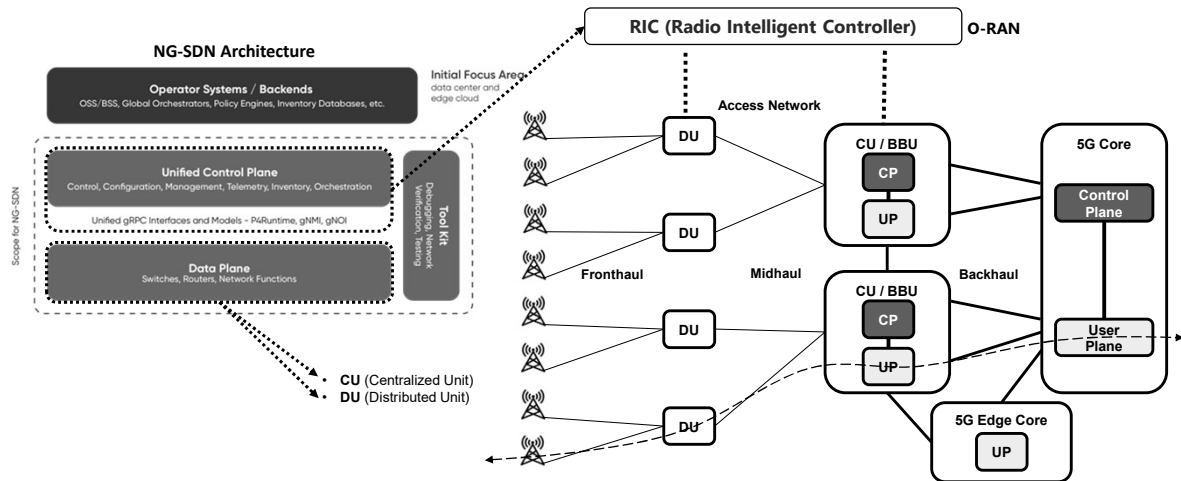
JS Lab

148

II. '가상화 (VIRTUALIZATION) 인프라'

149

❖ O-RAN과 '프론트홀/미드홀/백홀'



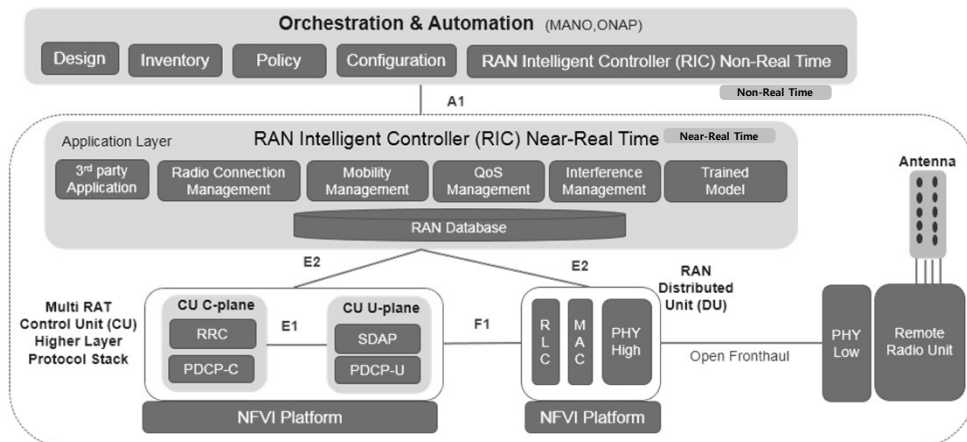
JS Lab

149

II. '가상화 (VIRTUALIZATION) 인프라'

150

❖ Open RAN (O-RAN) Reference Architecture



Source: <https://www.techplayon.com/open-ran-o-ran-reference-architecture/>

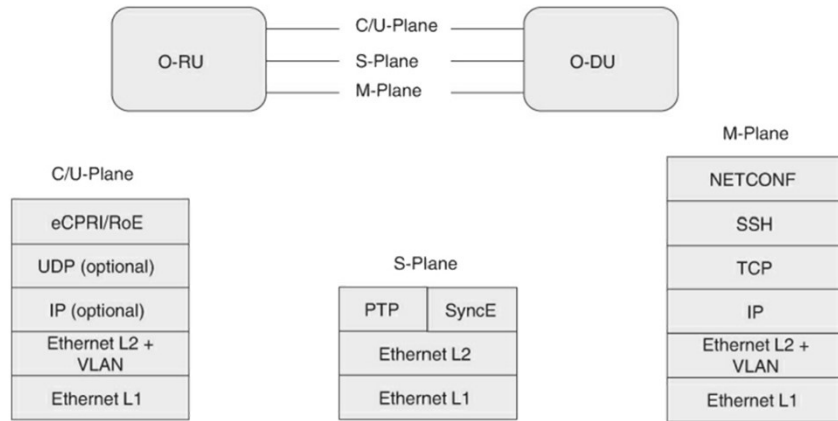
JS Lab

150

II. '가상화 (VIRTUALIZATION) 인프라'

151

❖ Details of Each of the Planes of the O-RAN Front-haul Interface



S-Plane (Synchronized) ... M-Plane (Management).
Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.



JS Lab

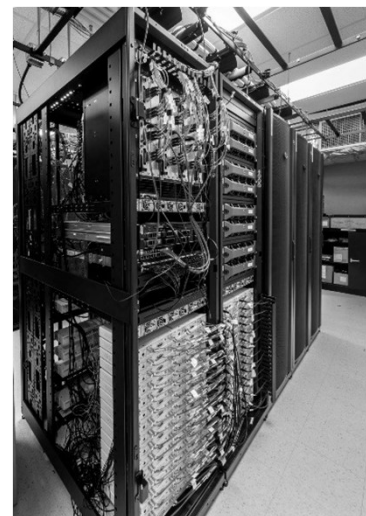
151

II. '가상화 (VIRTUALIZATION) 인프라'

152

❖ RAN 가상화를 위한 AI/ML @ O-RAN

- O-RAN 구성
- 256 software-defined radios
- 25.6 GHz of emulated bandwidth, 52 TB/s RF data
- 21 racks of radios, 171 high-performance servers w/ CPUs, GPUs
- Massive computing capabilities (CPU, GPU, FPGA):
 - > 900 TB of storage
 - 320 FPGAs
 - 18 10G switches
 - 19 clock distribution systems
 - 52 TB/s of digital RF data



N Institute for the Wireless
Internet of Things
at Northeastern



JS Lab

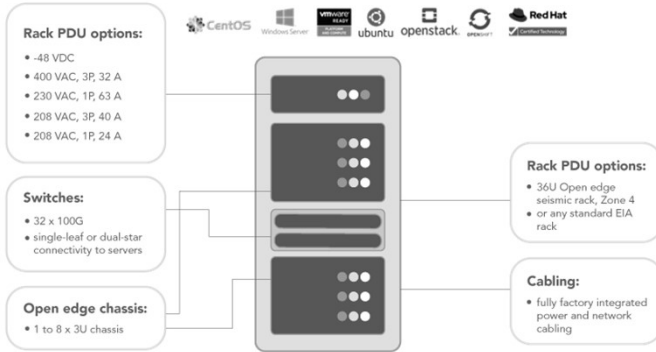
152

II. '가상화 (VIRTUALIZATION) 인프라'

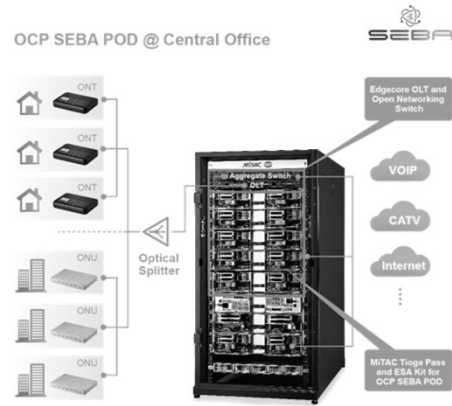
153

❖ 화이트박스(예) Access Edge Solution for Telco Central Office (OCP Marketplace)

Nokia AirFrame Open Edge Rack Solution



OCP SEBA POD @ Central Office



The Nokia AirFrame Open Edge Rack Solution, is an x86 solution built and tailored to fully support edge and far-edge cloud deployments Based on the Open Networking Foundation's (ONF) SDN Enabled Broadband Access architecture (SEBA)
Source: <https://www.opencompute.org/telecom-edge?page=2>

JS Lab

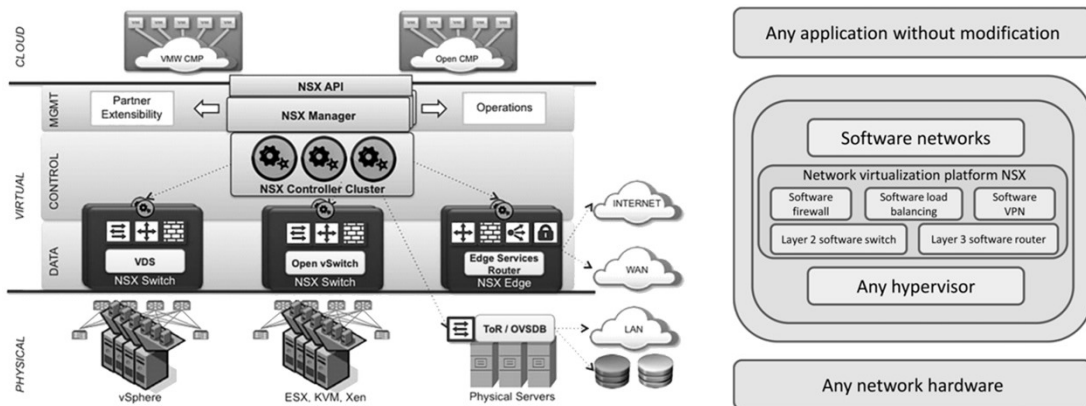
153

II. '가상화 (VIRTUALIZATION) 인프라'

154

❖ 제조사 SDN (VMware NSX)

- The NSX architecture (NSX-V → NSX-T)



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

154

II. '가상화 (VIRTUALIZATION) 인프라'

155

❖ 제조사 SDN (Cisco ACI)

• The ACI architecture



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

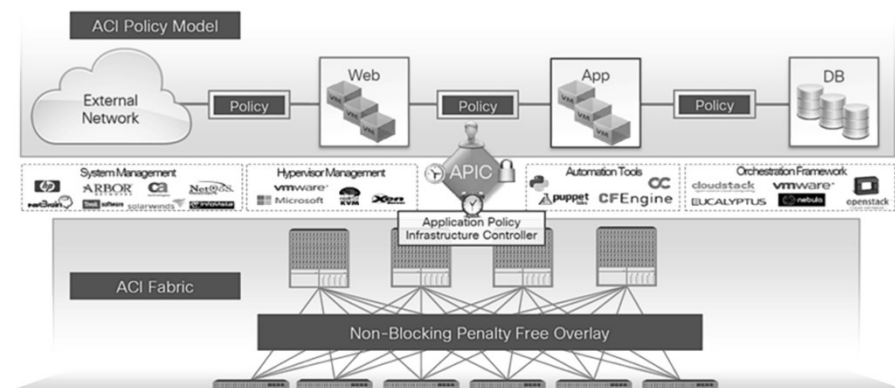
155

II. '가상화 (VIRTUALIZATION) 인프라'

156

❖ 제조사 SDN (Cisco ACI)

• Detailed ACI architecture



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

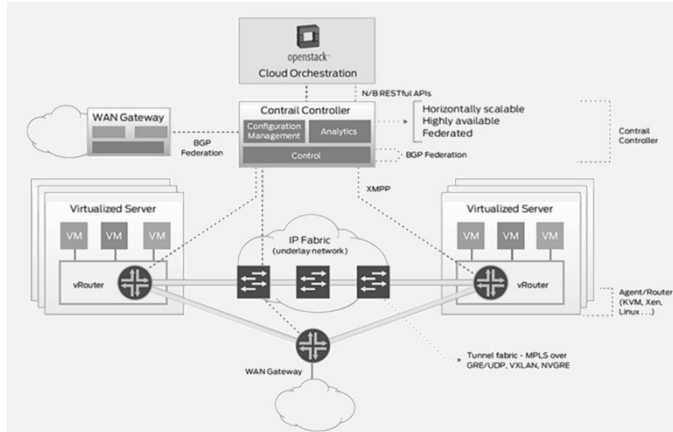
156

II. '가상화 (VIRTUALIZATION) 인프라'

157

❖ 제조사 SDN (Juniper)

- The OpenContrail platform from Juniper



XMPP: The Extensible Messaging and Presence Protocol

Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

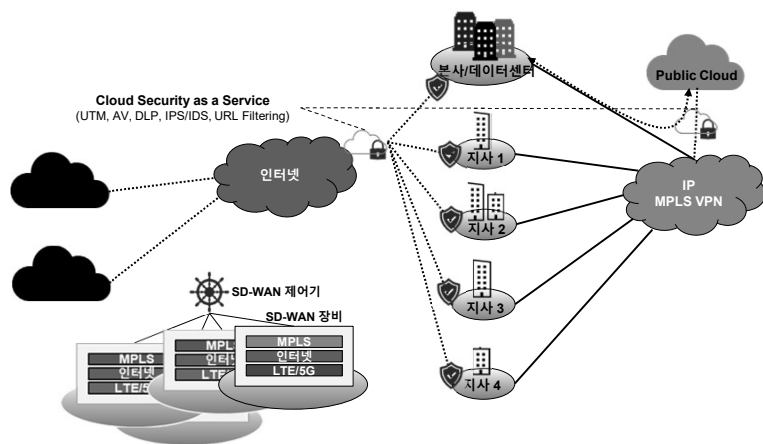
157

II. '가상화 (VIRTUALIZATION) 인프라'

158

❖ SD-WAN의 발전

- SD-WAN network



JS Lab

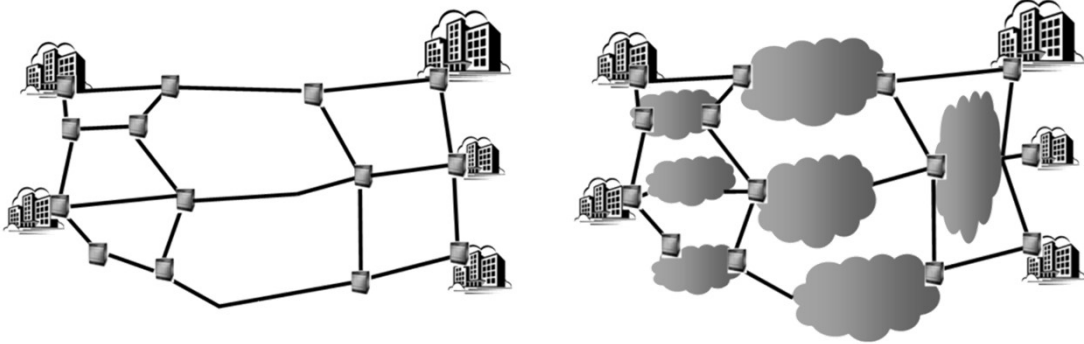
158

II. '가상화 (VIRTUALIZATION) 인프라'

159

❖ 오버레이 WAN 네트워크를 위한 SDN

- Overlay network of the SD-WAN network



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

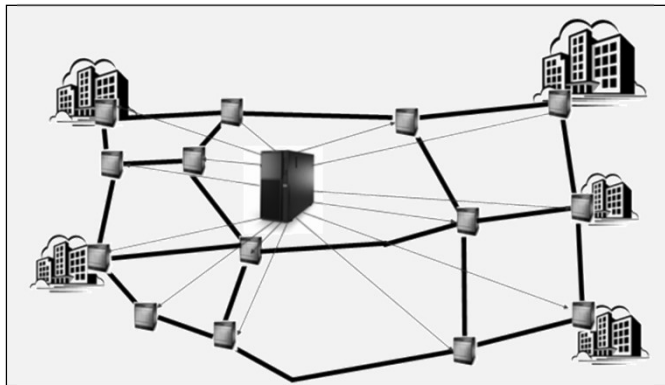
159

II. '가상화 (VIRTUALIZATION) 인프라'

160

❖ SD-WAN의 제어기

- SD-WAN network with its controller



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020



JS Lab

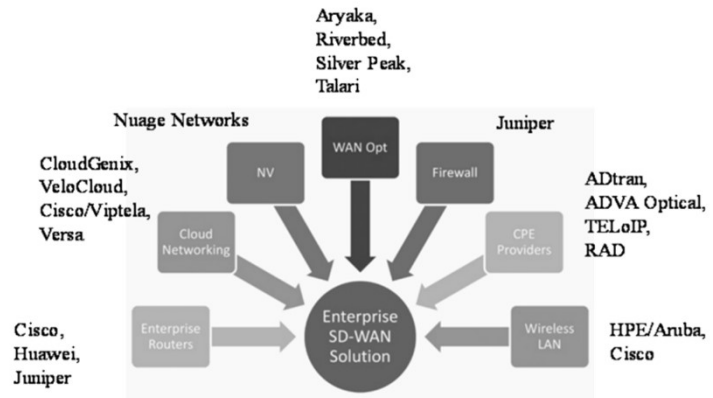
160

II. '가상화 (VIRTUALIZATION) 인프라'

161

❖ 엔터프라이즈 환경 SD-WAN의 발전

- Advantages of SD-WAN and some associated manufacturers



Secure access service edge (SASE)

Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

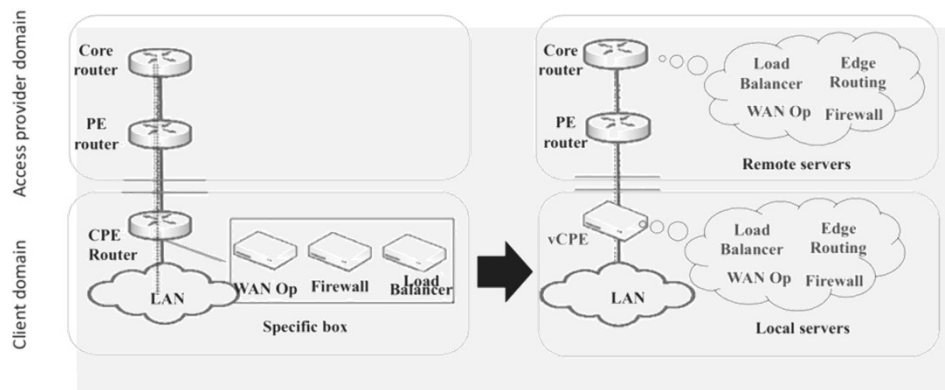
161

II. '가상화 (VIRTUALIZATION) 인프라'

162

❖ CPE 가상화 (하드웨어와 소프트웨어의 분리)

- Example of a vCPE with the hybrid architecture



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

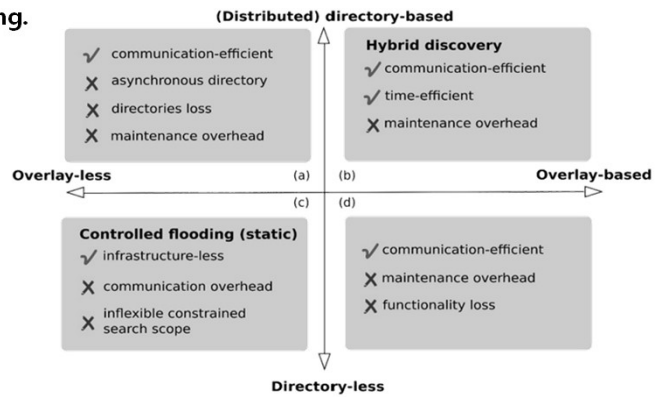
JS Lab

162

II. '가상화 (VIRTUALIZATION) 인프라'

163

- ❖ Dynamic Controlled Flooding:
 - a. distributed directory-based routing,
 - b. hybrid routing,
 - c. static-controlled routing, and
 - d. overlay-based routing controlled flooding.



Source: Chen, Nanxi. Mobile Microservices (p. 30). CRC Press. Kindle Edition.

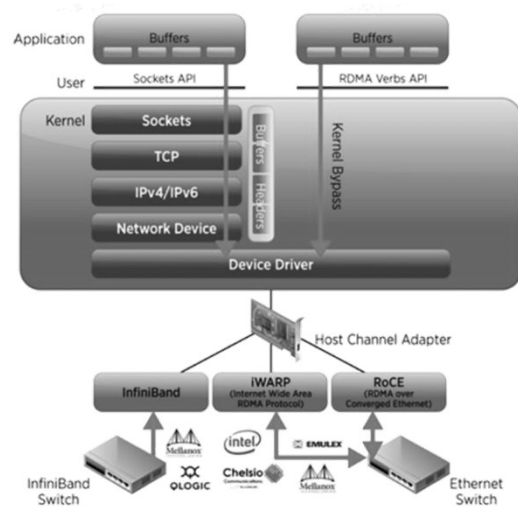
JS Lab

163

II. '가상화 (VIRTUALIZATION) 인프라'

164

- ❖ 가속을 위한 오프로드 하드웨어 구조



164

JS Lab

164

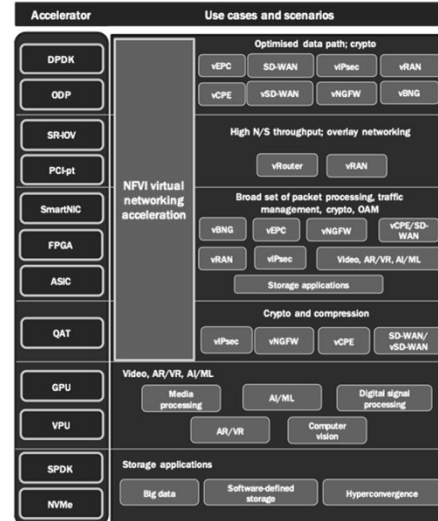
II. '가상화 (VIRTUALIZATION) 인프라'

165

❖ Acceleration technologies and use cases

- 가상화를 위한 가속 기술
- DPDK
- SR-IOV
- SmartNIC
- FPGA
- ASIC
- QAT
- GPU
- DPU
- IPU
- NVMe

Source: 5GPPP Architecture Working Group, 5G Architecture White Paper



JS Lab

165

III. '클라우드 서비스'

166

- 클라우드 5G 서비스 개요
- 컨테이너 기술
- 클라우드 네이티브 인프라 구축
- 서비스 메시

◆ ◆ ◆ ◆ james@jslab.kr

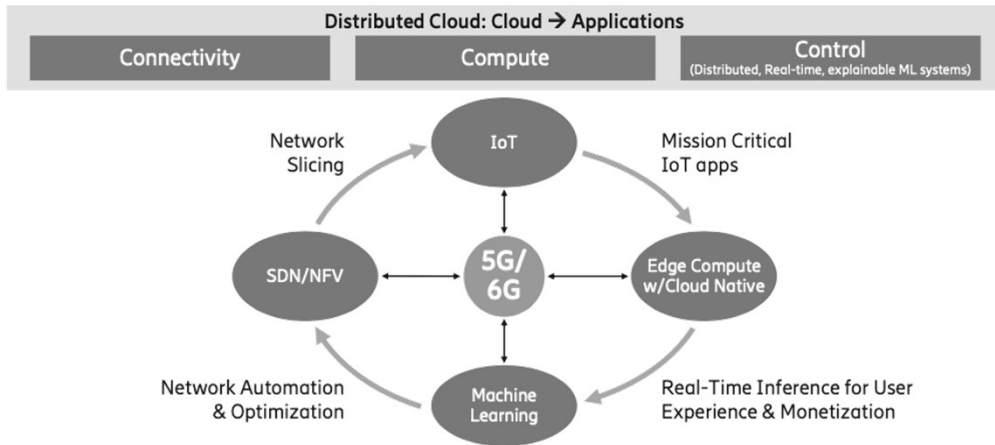
JS Lab

166

III. '클라우드 서비스'

167

❖ Transitioning From 5G To 6G



Source: <https://semiengineering.com/edps-transitioning-from-5g-to-6g/>

JS Lab

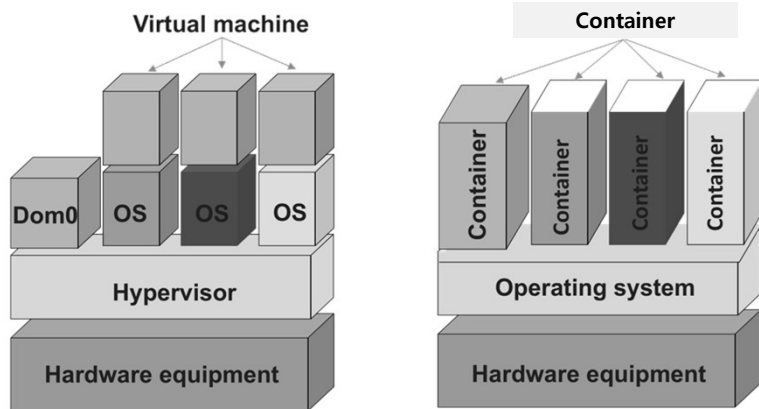
167

III. '클라우드 서비스'

168

❖ 가상화와 컨테이너

- A virtualized machine
- or Container



Source: Software Networks (Virtualization, SDN, 5G and Security), by ISTE Press Ltd and John Wiley & Sons, Inc. 2020

JS Lab

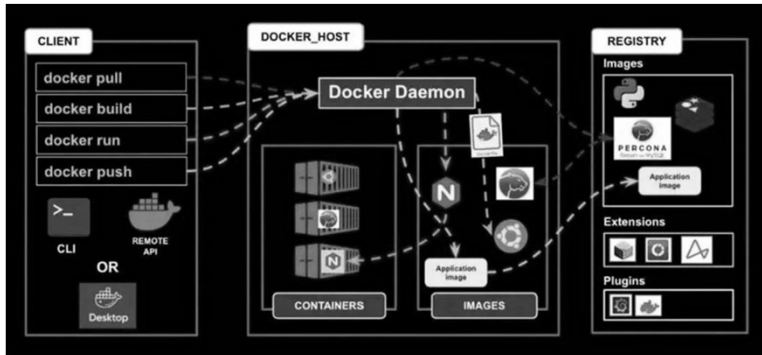
168

III. '클라우드 서비스'

169

❖ Docker Architecture

- docker pull percona - - - - -
- docker build . - - - - -
- docker run - - - - -
- docker push <application image> - - - - -



Source: <https://www.facebook.com/groups/797077440420513/permalink/5382176308577247/?sfnsn=mo&ref=share&mibextid=uevf24>

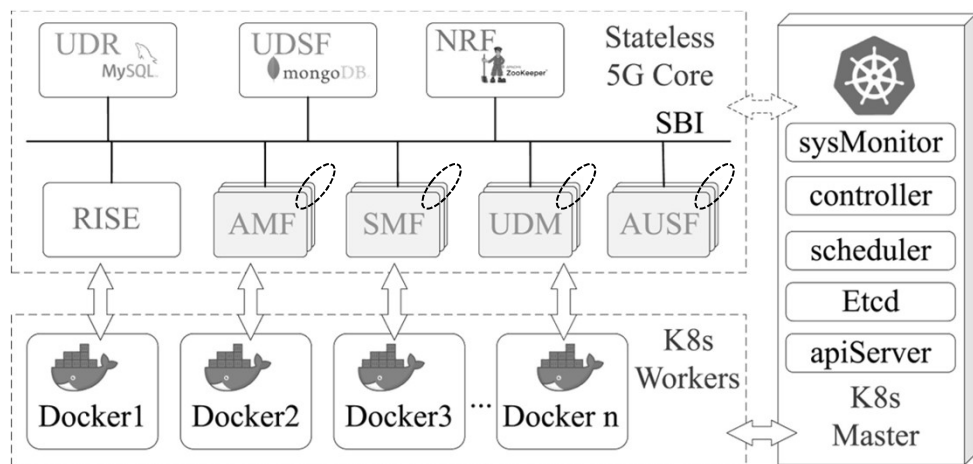
JS Lab

169

III. '클라우드 서비스'

170

❖ Architecture of message-level stateless 5G core network.



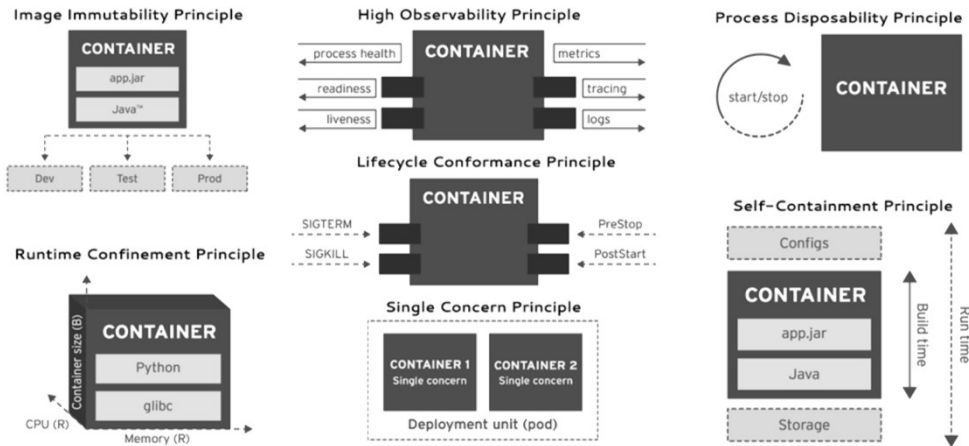
Source: <https://www.sciencedirect.com/science/article/pii/S2352864822000815>

JS Lab

170

III. '클라우드 서비스'

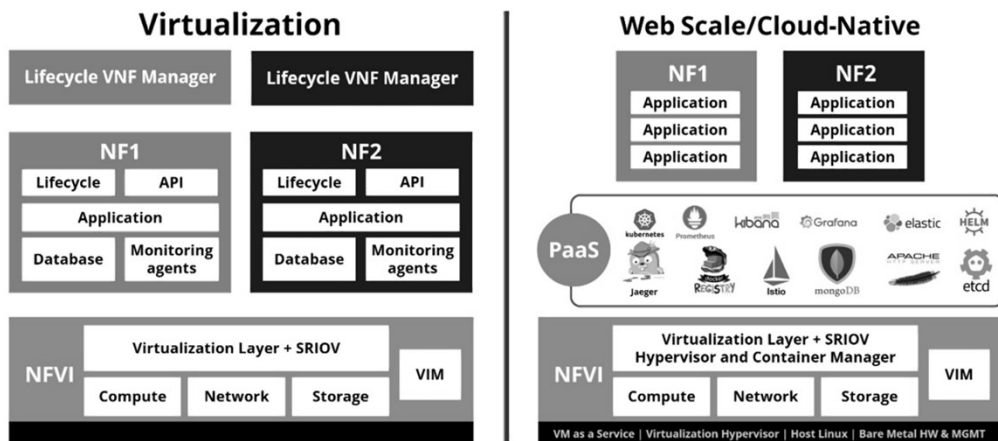
❖ Container-based Application Design



Source: <https://kubernetes.io/blog/2018/03/principles-of-container-app-design/?fbclid=IwAR2oMrdP0d1Q6LXebtxNPnt-RS5DlIkCwpaMSL5mmW7VMaQb6hRV8hk38>

III. '클라우드 서비스'

❖ Microservices-based architecture results in faster service creation & deployment



Source: White Paper—An Open Approach to Building 5G Networks – affirmed networks
 Source: <https://www.affirmednetworks.com/pdfs/an-open-approach-to-building-5g-networks.pdf/>

III. '클라우드 서비스'

173

❖ 클라우드 네이티브 (Cloud Native)

- 클라우드 네이티브 컴퓨팅 재단(CNCF)의 정의 (2018)
- 클라우드 네이티브 기술은 조직이 퍼블릭, 프라이빗, 그리고 하이브리드 클라우드와 같은 현대적이고 동적인 환경에서 확장 가능한 애플리케이션을 개발하고 실행할 수 있게 해준다. 컨테이너, 서비스 메쉬, 마이크로서비스, 불변(Immutable) 인프라, 그리고 선언형(Declarative) API가 이러한 접근 방식의 예시들이다.
- 이 기술은 회복성, 관리 편의성, 가시성을 갖춘 느슨하게 결합된 시스템을 가능하게 한다. 견고한 자동화 기능을 함께 사용하면, 엔지니어는 영향이 큰 변경을 최소한의 노력으로 자주, 예측 가능하게 수행할 수 있다.
- Cloud Native Computing Foundation은 벤더 중립적인 오픈 소스 프로젝트 생태계를 육성하고 유지함으로써 해당 패러다임 채택을 촉진한다. 우리 재단은 최신 기술 수준의 패턴을 대중화하여 이런 혁신을 누구나 접근 가능하도록 한다.

Source: <https://github.com/cncf/toc/blob/main/DEFINITION.md>

JS Lab

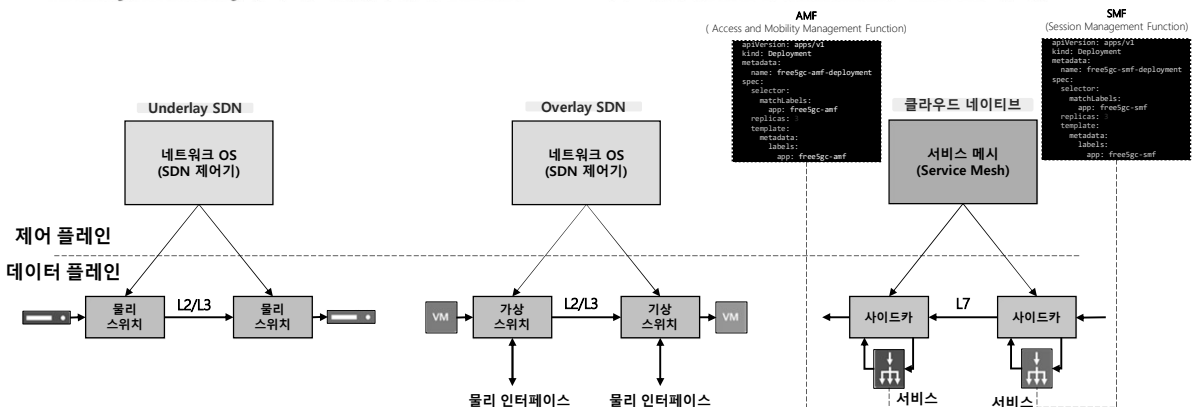
173

III. '클라우드 서비스'

174

❖ SDN (가상 네트워크)

- 오버레이 SDN의 분산처리: dSwitch, dRouter, dFW, dLB (VM 이동시 보안 정책 유지)
- 전용 제어기(SDN Controller) 사용
- Overlay/Underlay (물리/가상) 연결: VxLAN 프로토콜 사용 (VLAN, Multicast, VxLAN 헤더)

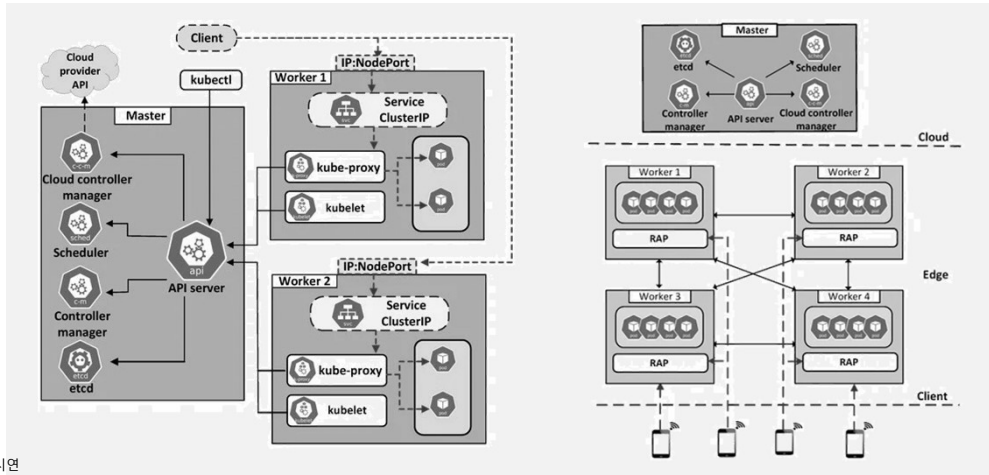


JS Lab

174

III. '클라우드 서비스'

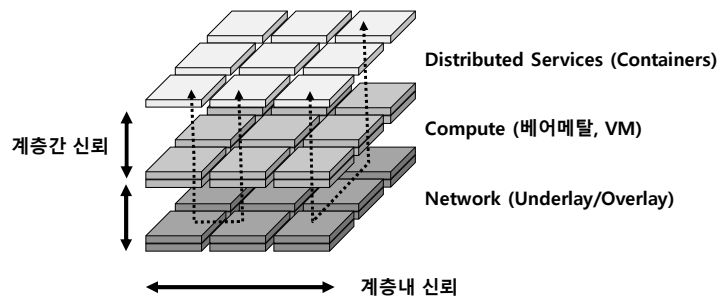
- ❖ Load-Balancing of Kubernetes-Based Edge Computing Infrastructure
 - Using Resource Adaptive Proxy (RAP) for Mobile



Kubernetes 자원 할당 (예) 시연
 Source: <https://www.mdpi.com/1424-8220/22/8/2869/htm>

III. '클라우드 서비스'

- ❖ 클라우드 계층 고려 인프라 보안
- ❖ 클라우드 계층 기반 보안 체계
 - 클라우드/SDDC/하드웨어 계층간 격리
 - 외부 서비스의 노출 정책 지정 (Ingress, LB, DMZ)
 - 계층내 신뢰 정책 강화

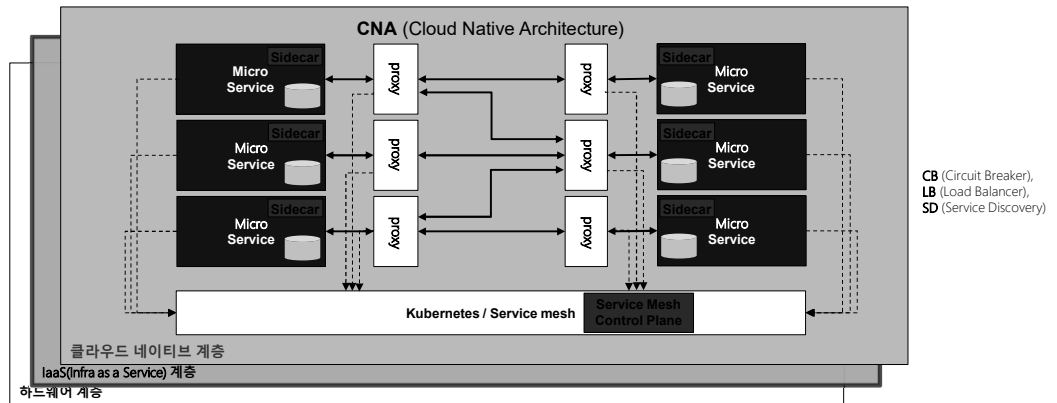


III. '클라우드 서비스'

177

❖ CNA 의 서비스 메시 관리

- Sidecar Design Pattern: 라우터 내장 CB, LB, SD 내장
- CNCF의 'Istio'는 정책 강화 Telemetry 제공



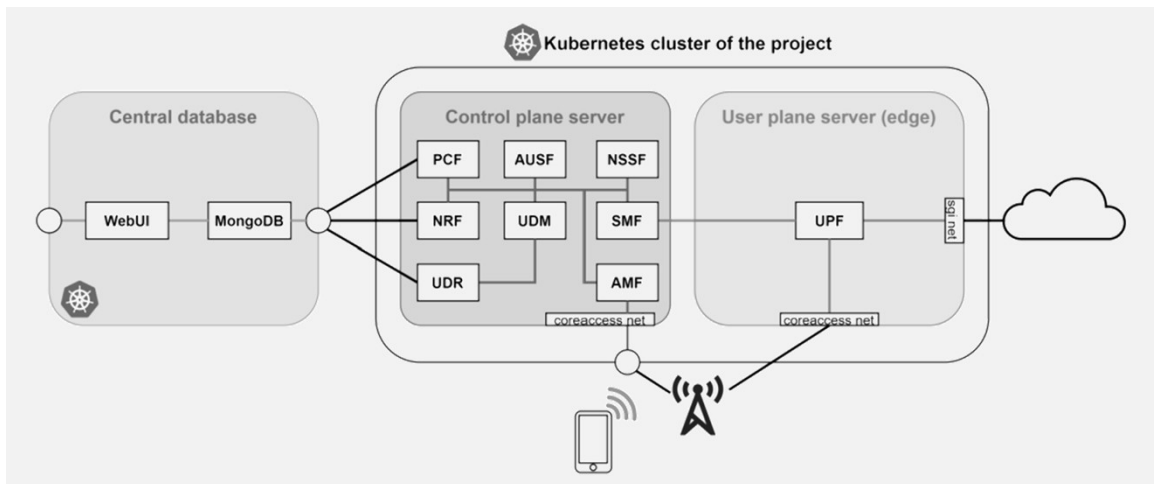
JS Lab

177

III. '클라우드 서비스'

178

❖ Containerized core network approach



Source: 5GPPP Architecture Working Group, 5G Architecture White Paper

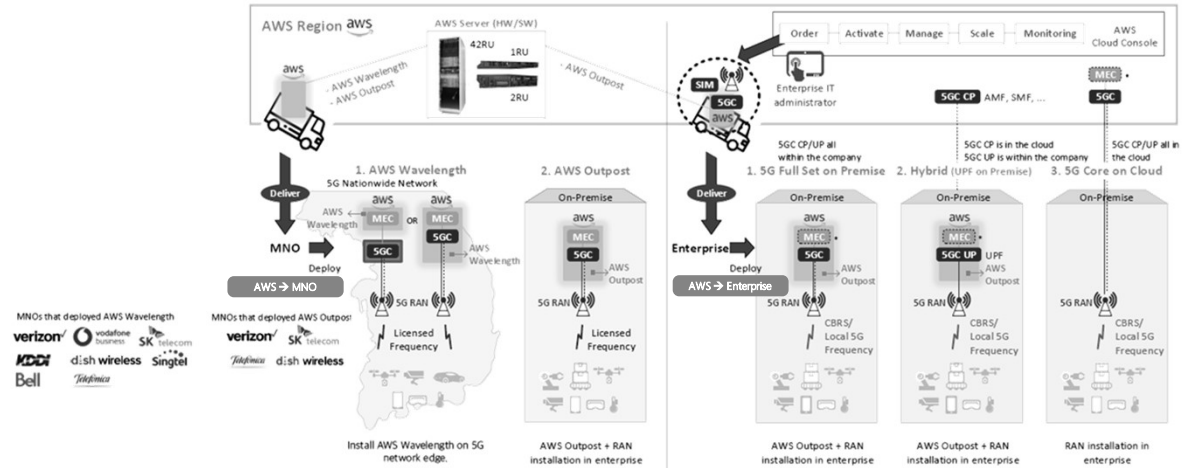
JS Lab

178

III. '클라우드 서비스'

❖ AWS Private 5G for enterprises and AWS Wavelength for mobile operators

Source links: AWS re-Invent 2021, 2021.11.11 >>, AWS, Next-Generation Mobile Private Networks Powered by AWS, 2021.01 >>, AWS, Private Mobile Edge Computing and 5G, 2021.03 >>

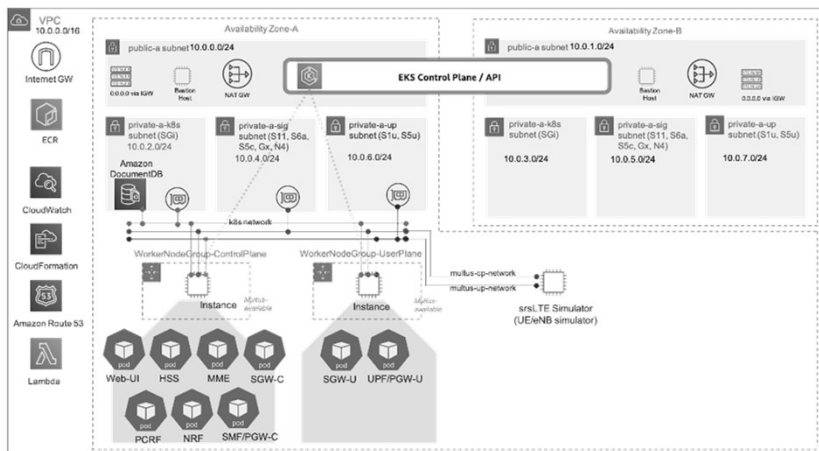


Source: <https://www.netmanias.com/en/?m=view&id=oneshot&no=15352>

III. '클라우드 서비스'

❖ 클라우드 서비스의 모바일 코어 네트워크 (예): Amazon Elastic Kubernetes Service

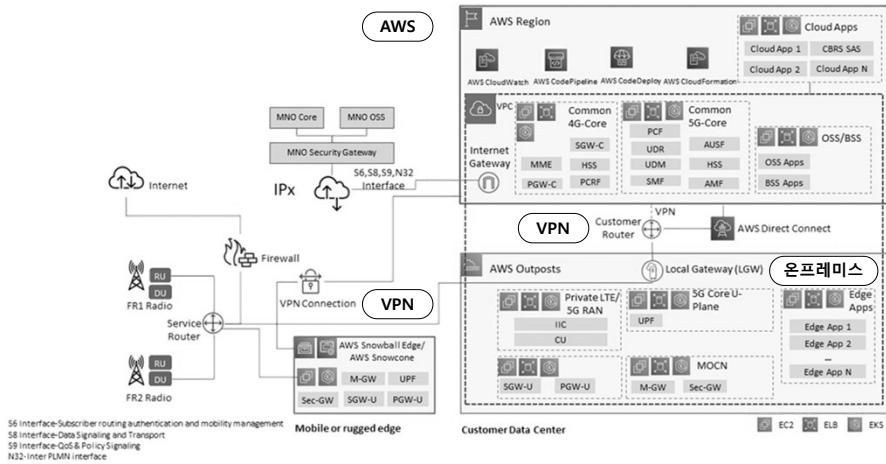
Time to complete	About 45-60 minutes
Cost to complete (estimated)	\$489 (for a month, on-demand instance cost based)
Learning level	Advanced (300)
Services used	AWS CloudFormation, Amazon Elastic Kubernetes Service, Amazon DocumentDB, AWS Lambda, Amazon CloudWatch



Source: <https://aws.amazon.com/blogs/opensource/open-source-mobile-core-network-implementation-on-amazon-elastic-kubernetes-service/>

III. '클라우드 서비스'

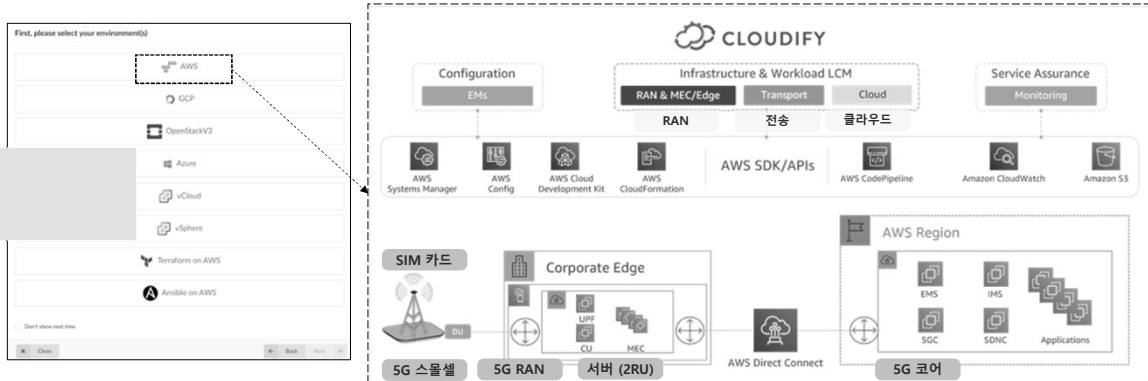
❖ Private 4G/5G on AWS, Deloitte Private Networks Lab Houston.



III. '클라우드 서비스'

❖ Cloudify: AWS 서비스에 5G 네트워크 슬라이싱 적용

- 멀티클라우드 오케스트레이션: Cloudify is for multi-cloud orchestration
- 아마존 AWS 적용 (예): Cloudify architecture on AWS.

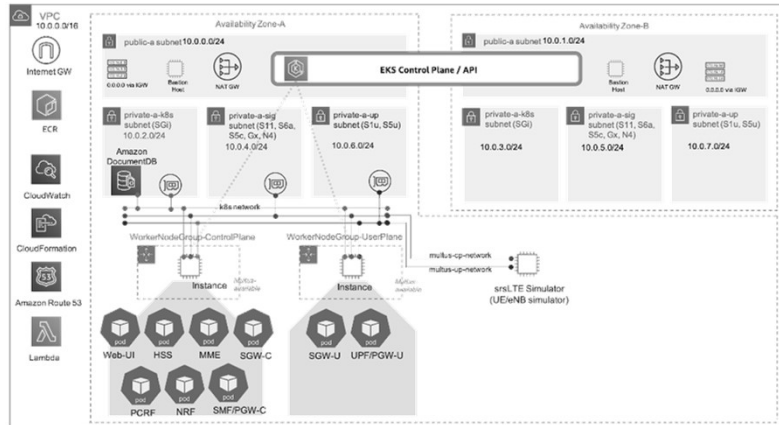


III. '클라우드 서비스'

183

❖ CSP (예): AWS

- Open source mobile core network implementation on Amazon Elastic Kubernetes Service



Source: <https://aws.amazon.com/blogs/opensource/open-source-mobile-core-network-implementation-on-amazon-elastic-kubernetes-service/>

JS Lab

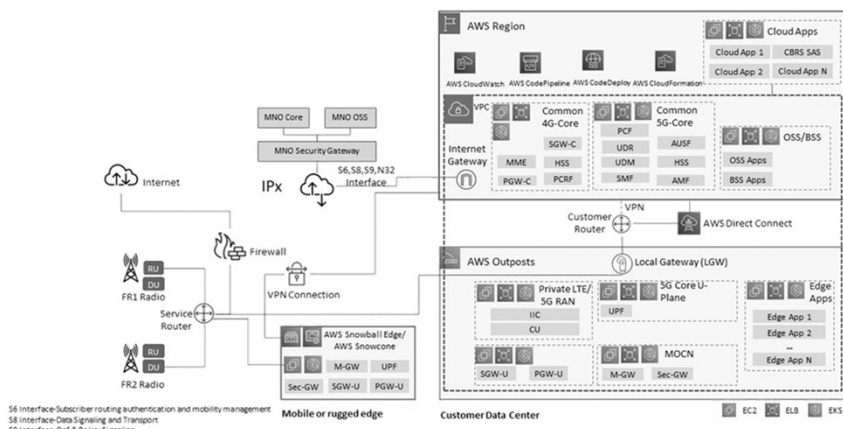
183

III. '클라우드 서비스'

184

❖ CSP (예): AWS

- Private 4G/5G on AWS, Deloitte Private Networks Lab Houston



Source: <https://aws.amazon.com/blogs/apn/scalable-mobile-private-4g-and-5g-network-services-on-aws-from-deloitte/>

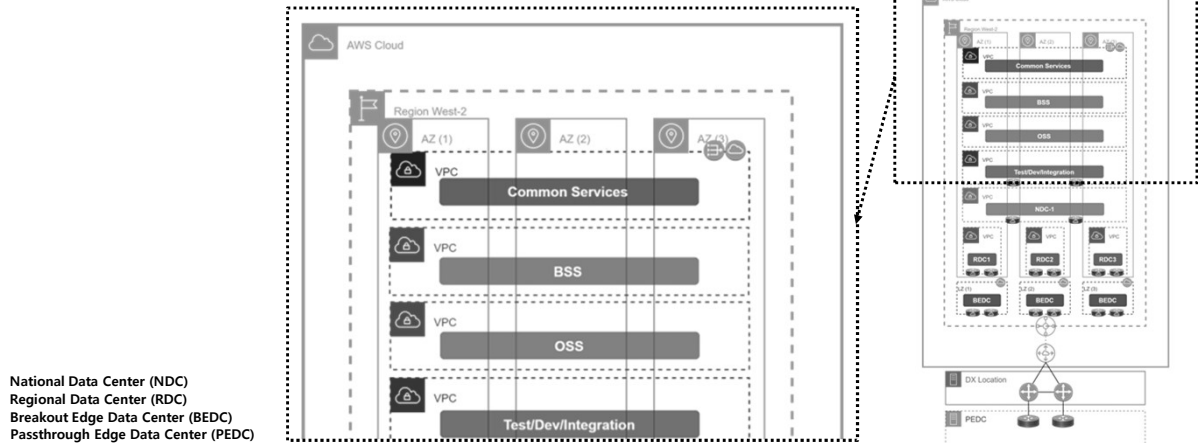
JS Lab

184

III. '클라우드 서비스'

❖ CSP (예): AWS

- Telco Meets AWS Cloud: Deploying DISH's 5G Network in AWS Cloud

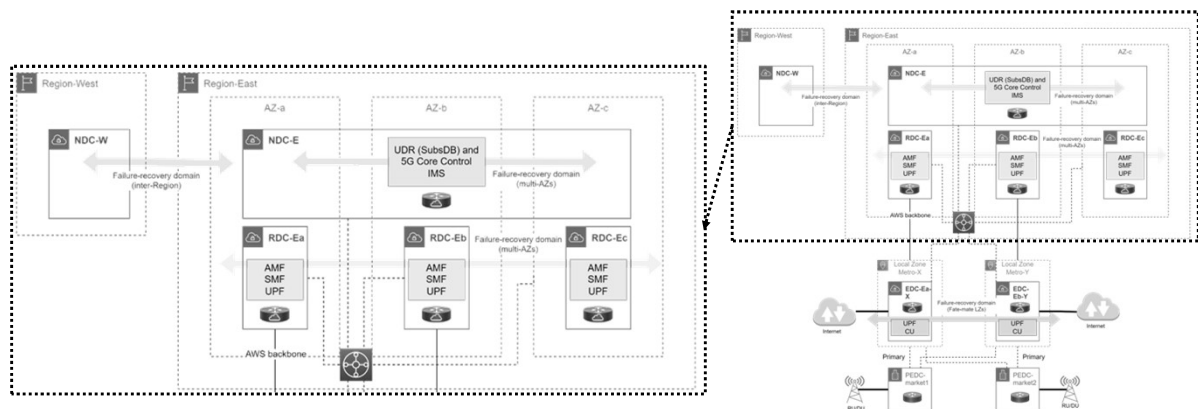


Source: <https://aws.amazon.com/blogs/industries/telco-meets-aws-cloud-deploying-dishs-5g-network-in-aws-cloud/>

III. '클라우드 서비스'

❖ CSP (예): AWS

- Network Resilience and Failover Scenarios

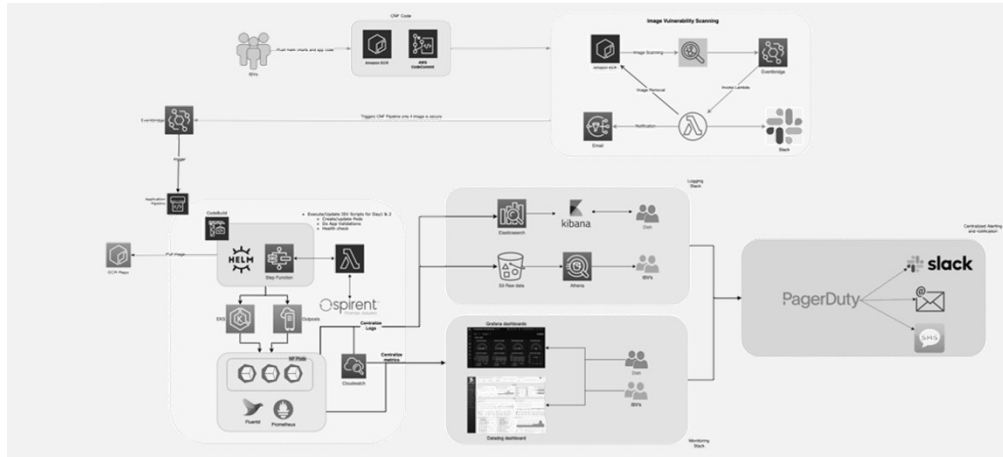


Source: <https://aws.amazon.com/blogs/industries/telco-meets-aws-cloud-deploying-dishs-5g-network-in-aws-cloud/>

III. '클라우드 서비스'

187

- ❖ CSP (예): AWS
 - DISH CI/CD Pipeline Architecture



Source: <https://aws.amazon.com/blogs/industries/telco-meets-aws-cloud-deploying-dishs-5g-network-in-aws-cloud/>

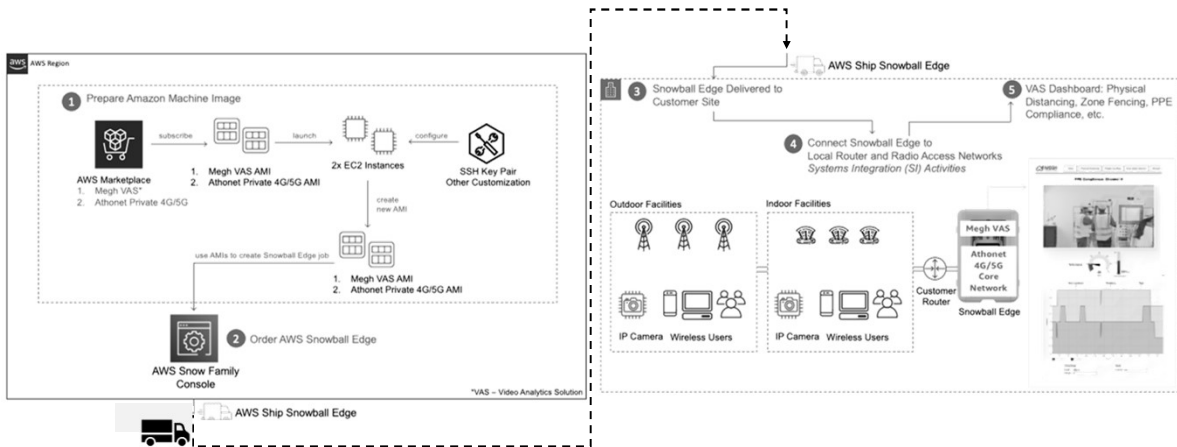
JS Lab

187

III. '클라우드 서비스'

188

- ❖ CSP(예): Private 4G/5G and video analytics for industrial sites with AWS Snowball Edge



Source: <https://aws.amazon.com/blogs/industries/private-4g-5g-and-video-analytics-for-industrial-sites-with-aws-snowball-edge/>

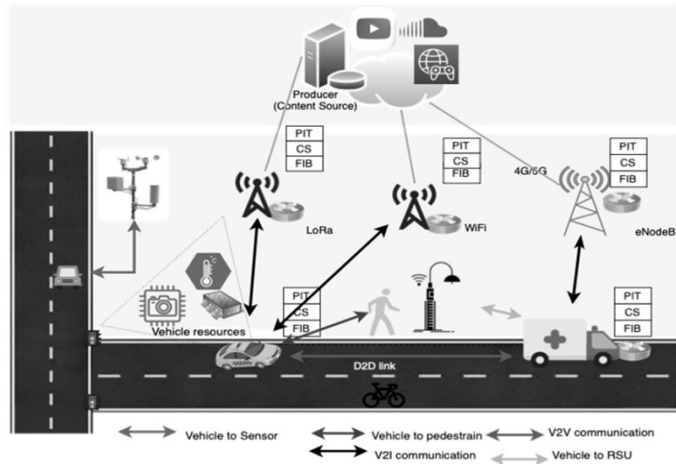
JS Lab

188

III. '클라우드 서비스'

189

❖ Converged Architecture for IloV (Intelligent Internet of Vehicles)



JS Lab

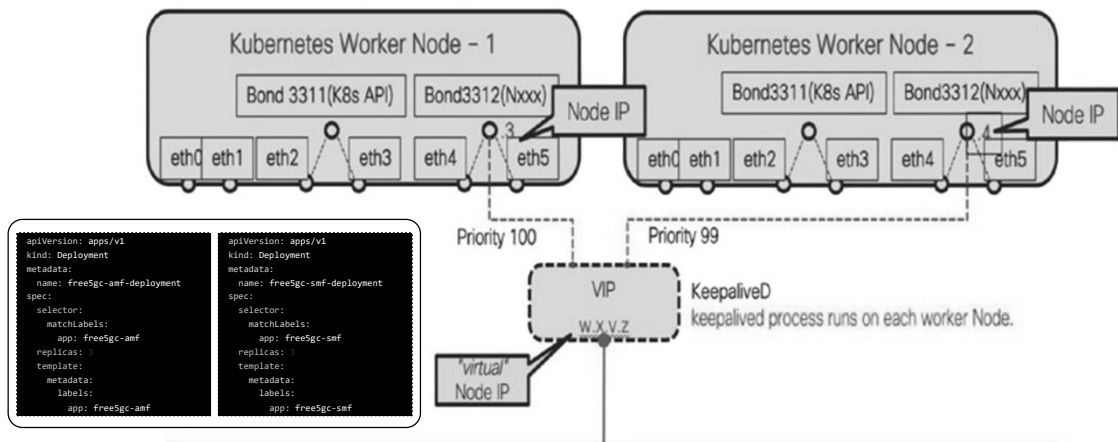
189

III. '클라우드 서비스'

190

❖ Illustration of Service redundancy (배포)

Example - Part of CNF (AMF, SMF, etc)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

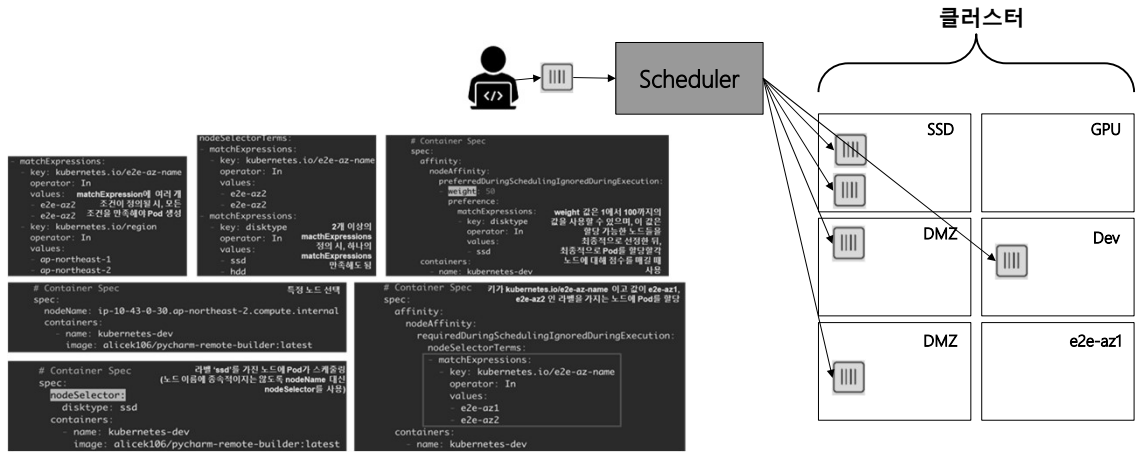


JS Lab

190

III. '클라우드 서비스'

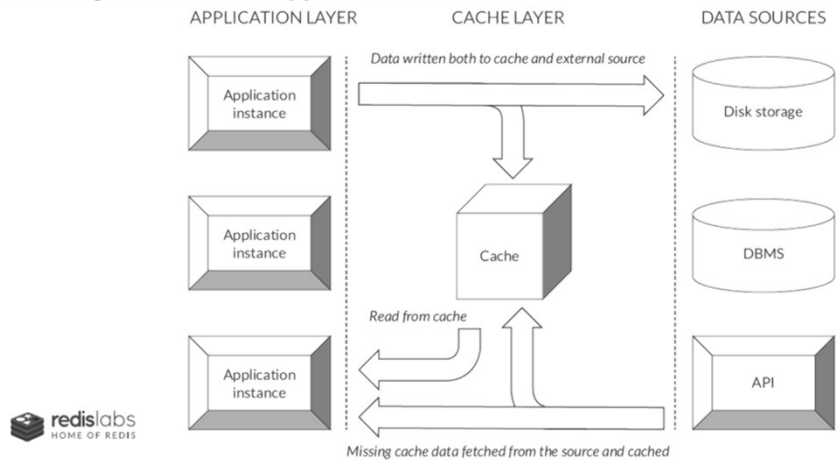
❖ Distributed system scheduler in action



III. '클라우드 서비스'

❖ Application Cache

- Faster intermediate data storage is called the application's cache

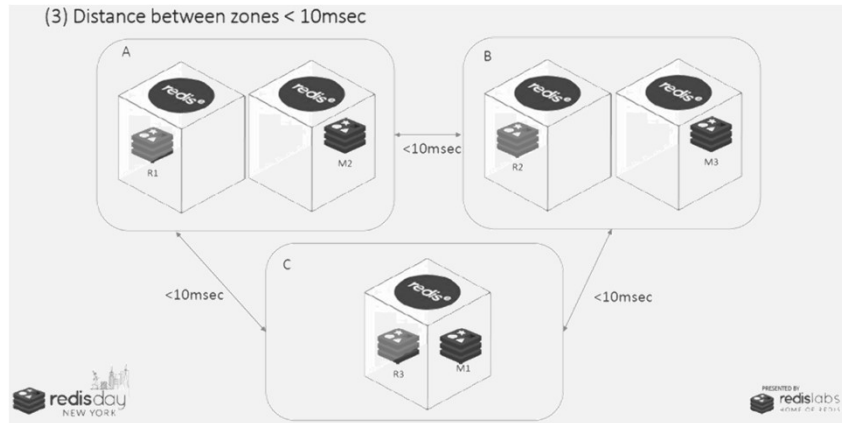


III. '클라우드 서비스'

193

❖ HA Concept @ Application Cache (예: Redis)

- Deploy a multi-az/rack cluster
- Master and replica of each shard should be deployed on a different zone



JS Lab

193

III. '클라우드 서비스'

194

❖ Redis vs. Memcached @ Application Cache

	Redis	Memcached
Persistence	Provides persistence storage and is a replacement for DB	Purely a caching solution and uses DB as the origin of the data
Object type	Complex data objects such as hashes, lists, sets etc.	Simple key value storage
Scaling	Vertical scaling supported. Horizontal Scaling not possible. Read Replicas can be created	Vertical and Horizontal Scaling supported
Multi-AZ	Multi-AZ supported & Automatic failover to the backup node	Multi-AZ not supported
Backup & Restore	Backup & Restore capabilities supported	Backup & Restore capabilities not supported
Pub/Sub capabilities	Pub/Sub capabilities provided	Pub/Sub capabilities not provided
Size	Values up to 512MB per key	Values up to 1MB per key

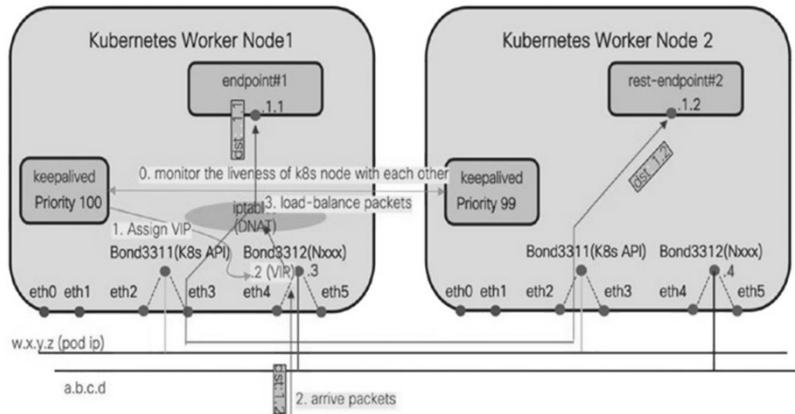
JS Lab

194

III. '클라우드 서비스'

195

❖ Illustration of Service redundancy - 정상 동작 시나리오



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

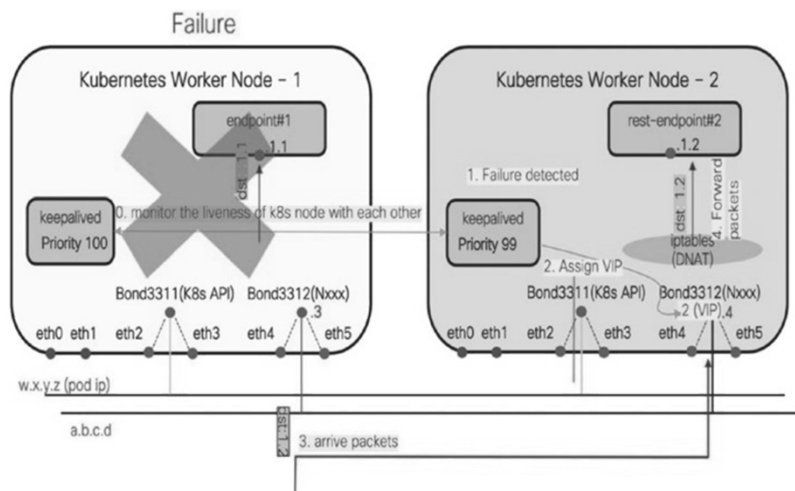
JS Lab

195

III. '클라우드 서비스'

196

❖ Illustration of Service redundancy - 장애 시나리오



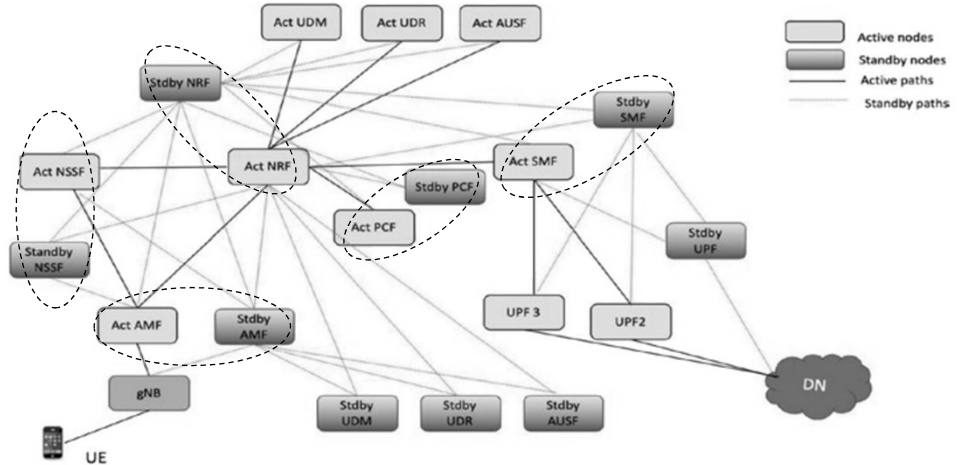
Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

JS Lab

196

III. '클라우드 서비스'

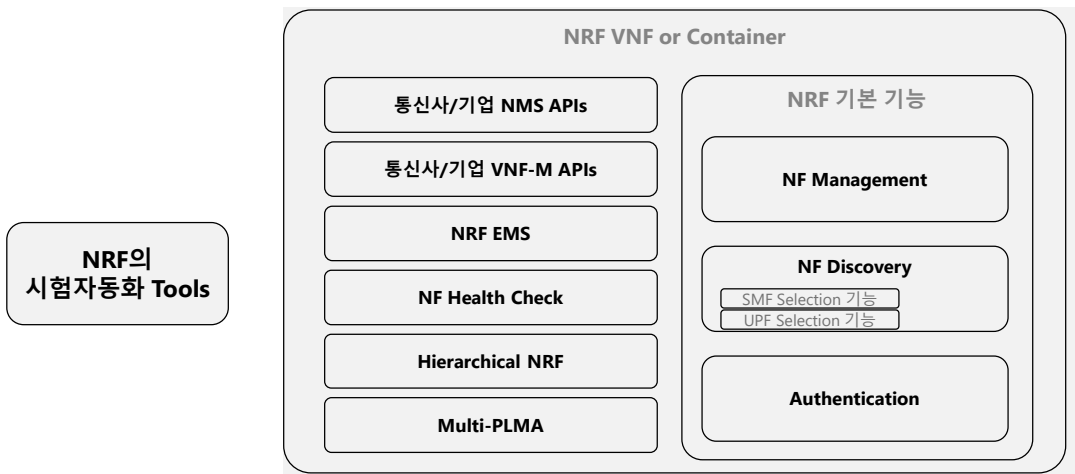
❖ 리던던트 레이아웃 (Redundancy layout for a simple Release15 5G SA network)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

III. '클라우드 서비스'

❖ 5G 표준에서 'VNF and/or CNF'를 위해 도입한 NRF

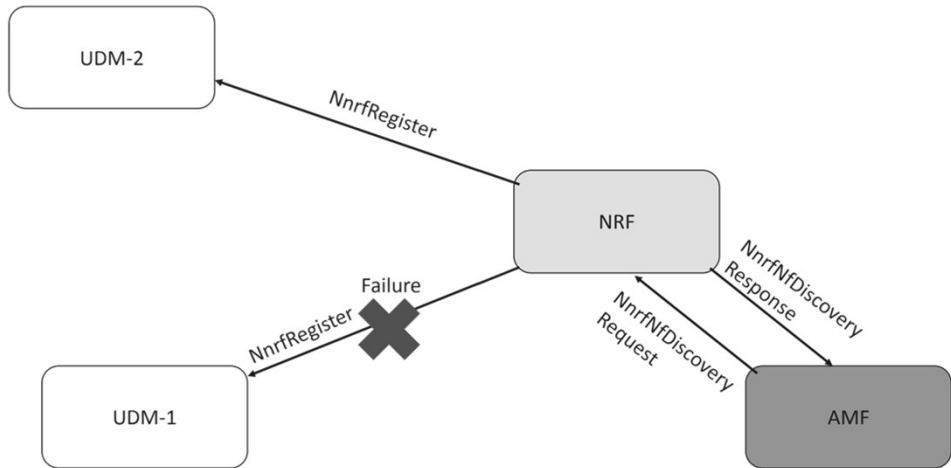


제조사 NRF 참조: 부록5, 제조사 NRF

III. '클라우드 서비스'

199

❖ NRF의 Node failure handling



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress



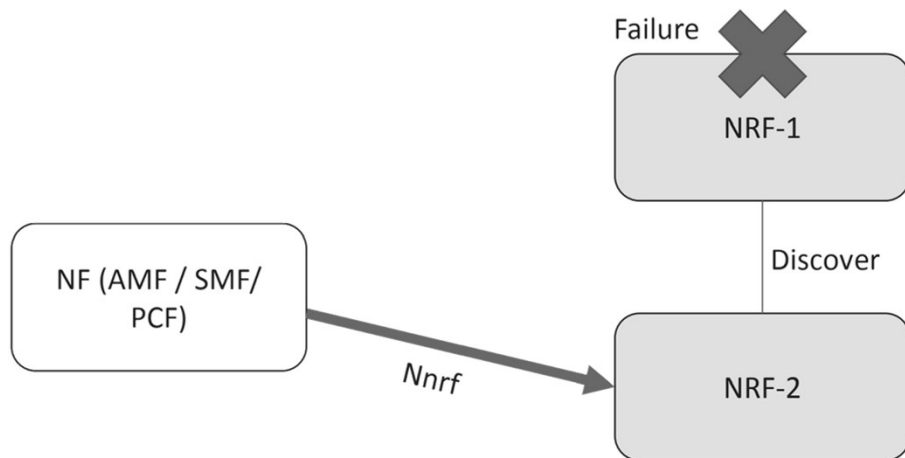
JS Lab

199

III. '클라우드 서비스'

200

❖ NRF failure handling



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

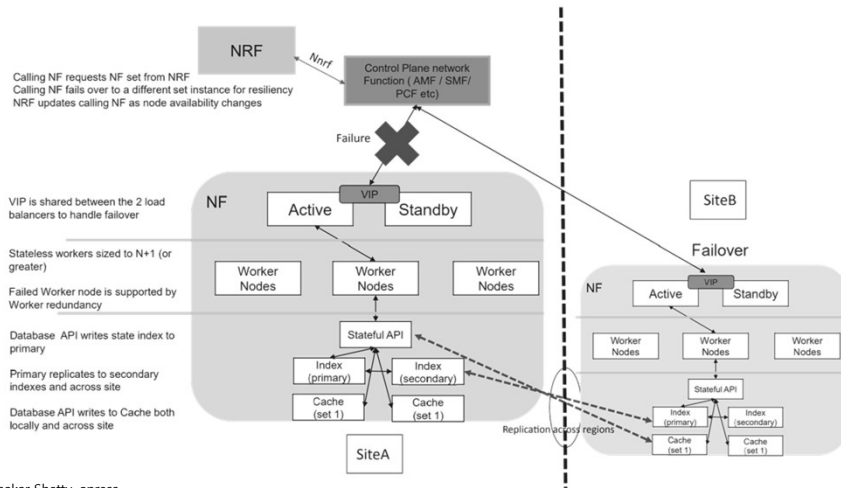


JS Lab

200

III. '클라우드 서비스'

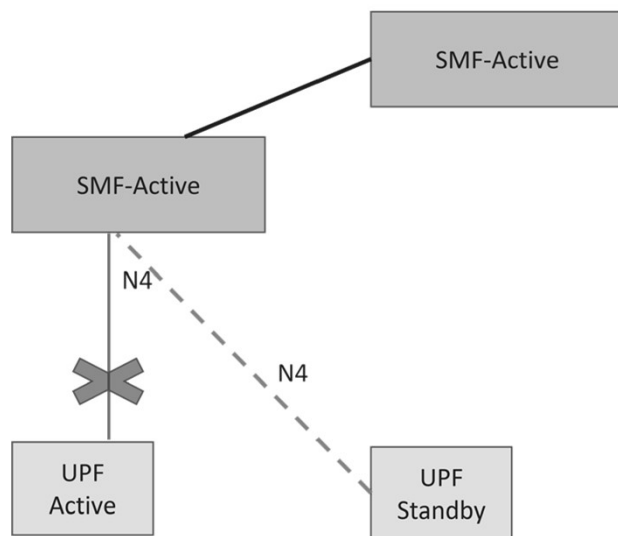
❖ Geographical redundancy for control plane network functions



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

III. '클라우드 서비스'

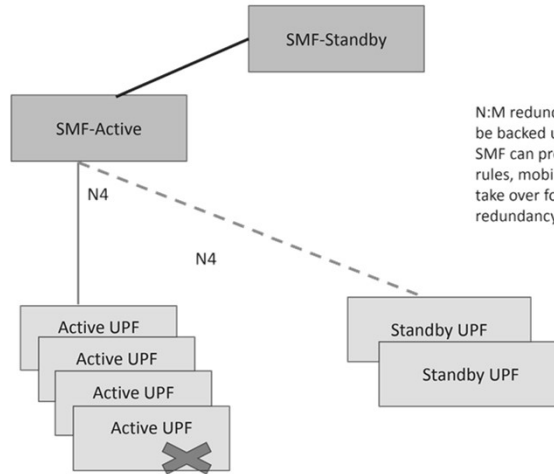
❖ 1:1 user plane redundancy



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

III. '클라우드 서비스'

❖ N:M user plane redundancy



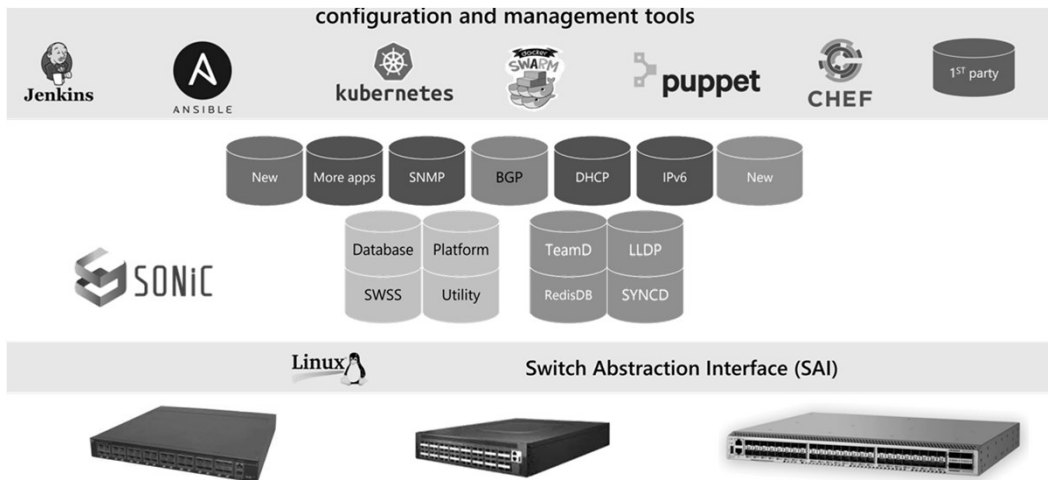
N:M redundancy requires state stored in the UPF and be backed up on the SMF
SMF can program a standby UPF with the required pcc-rules, mobile pools and session state information to take over for the failed UPF and provide data plane redundancy.

Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress



III. '클라우드 서비스'

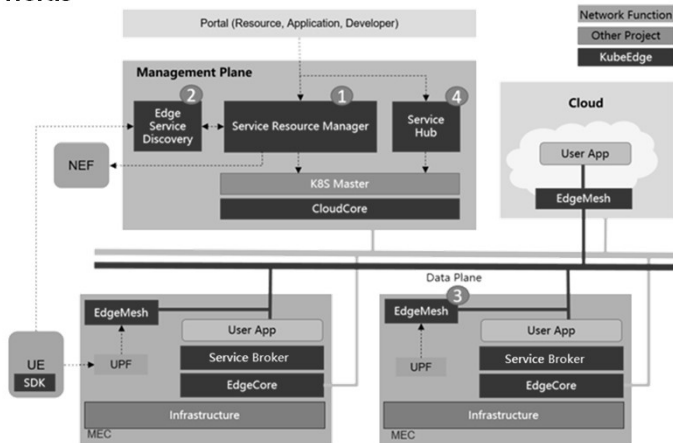
❖ SONiC (Software for Open Networking in the Cloud)



III. '클라우드 서비스'

- ❖ KubeEdge MEC SIG (예)
- ❖ MEC SIG focuses on the following fields

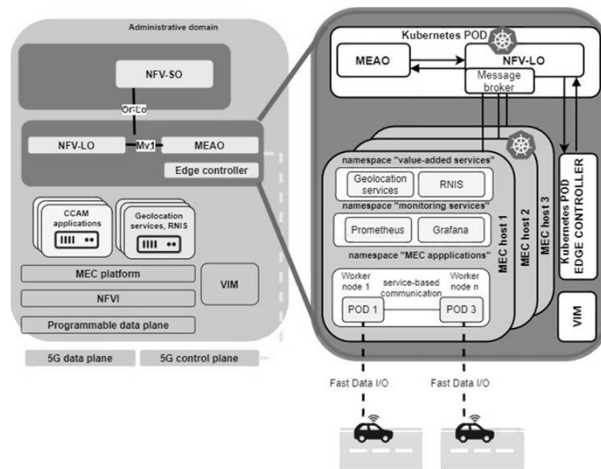
- ① Service Resource Manager
- ② Edge Service Discovery
- ③ EdgeMesh
- ④ ServiceHub



Source: <https://www.cncf.io/blog/2021/07/20/kubeedgemec-combining-the-kubernetes-ecosystem-with-5g/>

III. '클라우드 서비스'

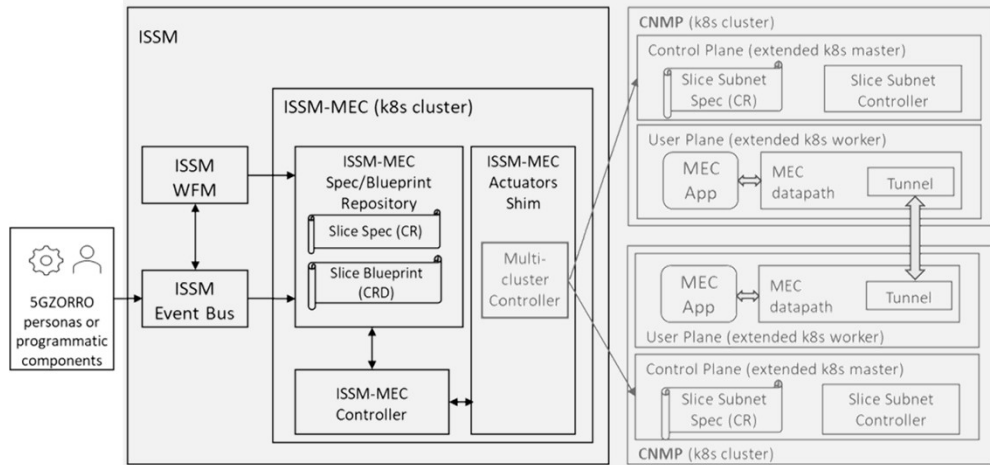
- ❖ Cloud-native design of the 5G Edge Orchestration Platform in an ETSI MEC context



Source: 5GPPP Architecture Working Group, 5G Architecture - White Paper

III. '클라우드 서비스'

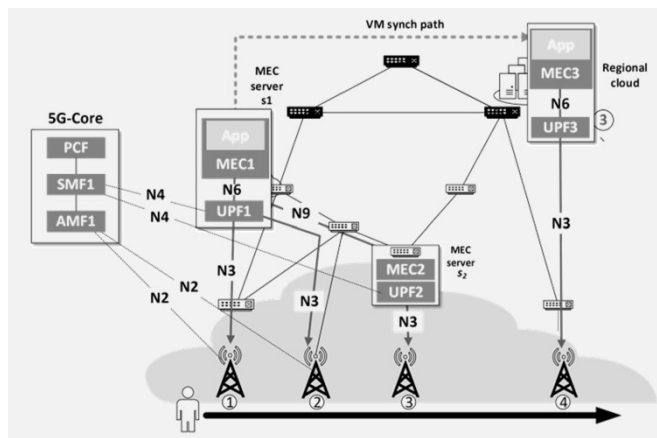
❖ Cloud-native MEC platform



Source: 5GPPP Architecture Working Group, 5G Architecture - White Paper

III. '클라우드 서비스'

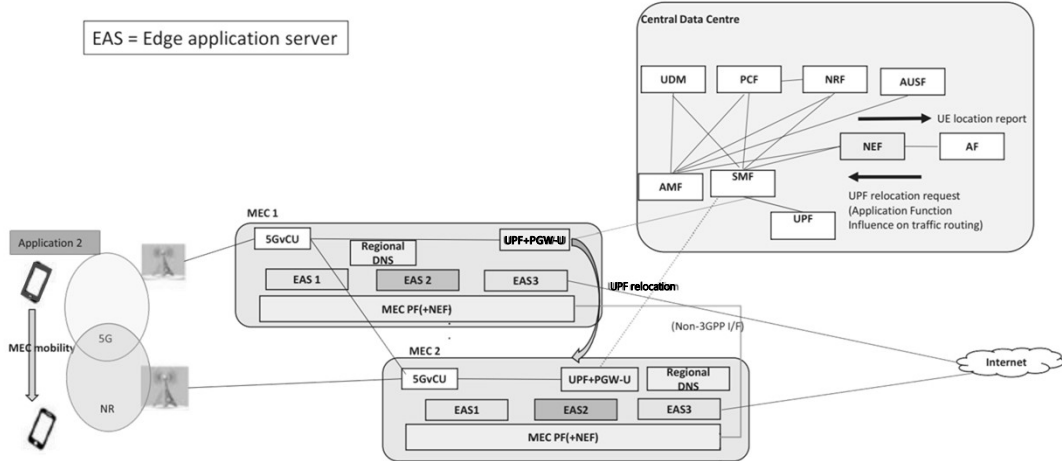
❖ Joint user handover and VM migration problem to ensure service continuity in MEC-assisted 5G environments.



Source: 5GPPP Architecture Working Group, 5G Architecture - White Paper

III. '클라우드 서비스'

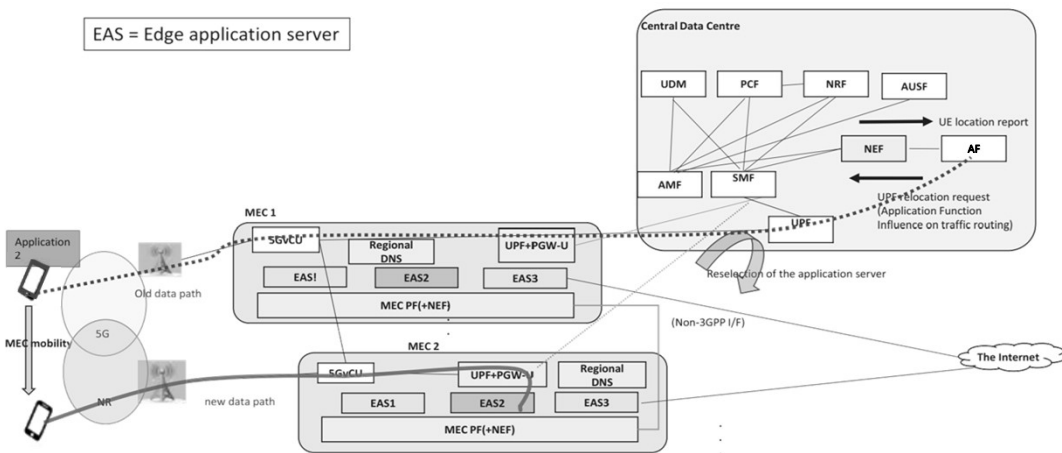
❖ Integrated MEC deployment in 5G network with UPF relocation



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

III. '클라우드 서비스'

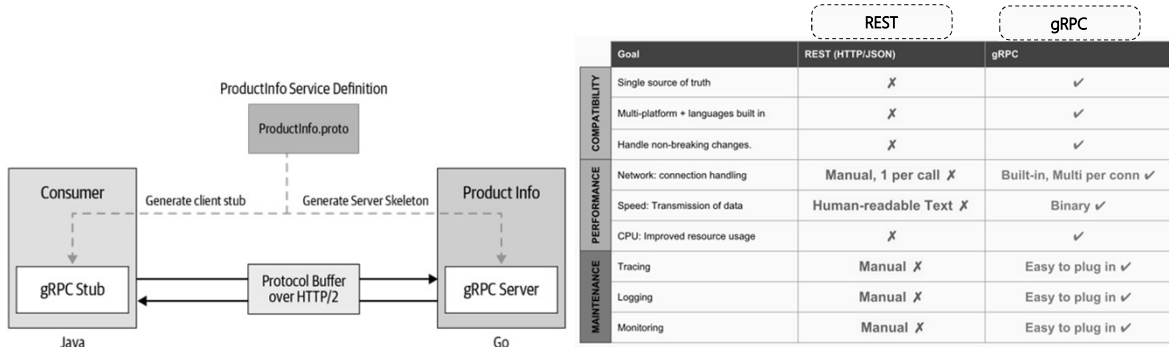
❖ Integrated MEC deployment in 5G network with application relocation



5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

III. '클라우드 서비스'

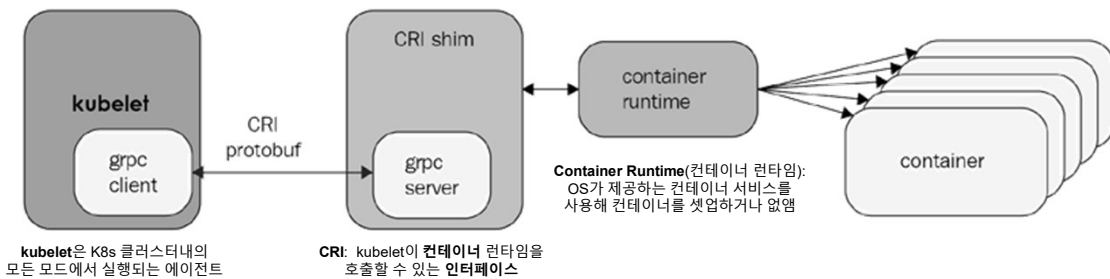
❖ A microservice and a consumer based on gRPC



gRPC는 어떤 환경에서도 동작하는 모던한 오픈소스 원격 프로시저 요청 (Remote Procedure Call, RPC) 프레임워크
 Source: <https://swagger.io/tools/swaggerhub/>

III. '클라우드 서비스'

❖ The container runtime interface (CRI) flow diagram

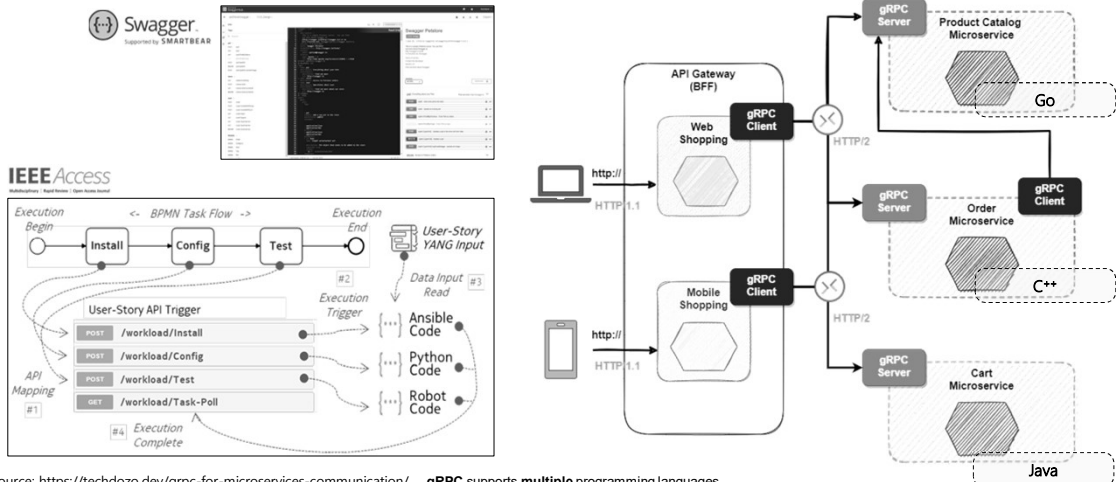


kubelet은 K8s 클러스터내의 모든 노드에서 실행되는 에이전트

CRI: kubelet이 컨테이너 런타임을 호출할 수 있는 인터페이스

III. '클라우드 서비스'

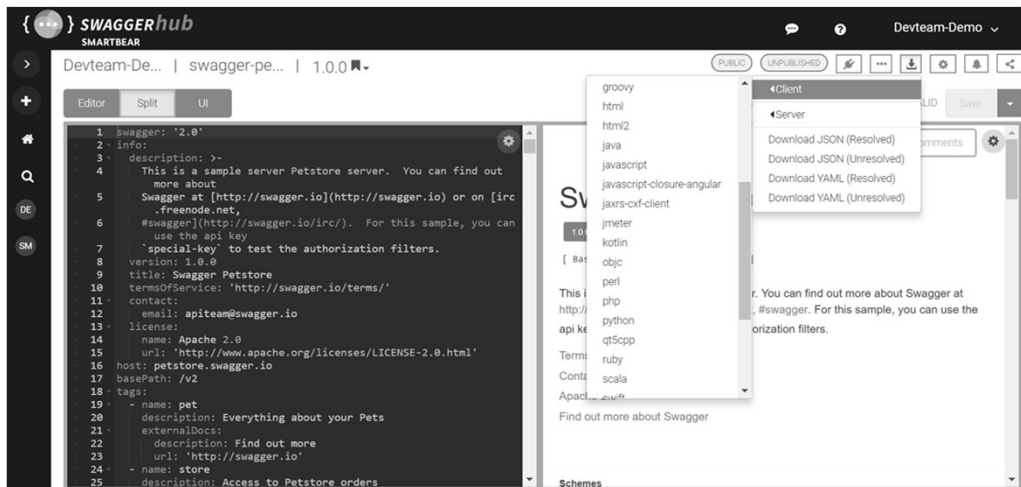
❖ gRPC application architecture (예)



Source: <https://techdozo.dev/grpc-for-microservices-communication/>, gRPC supports multiple programming languages.

III. '클라우드 서비스'

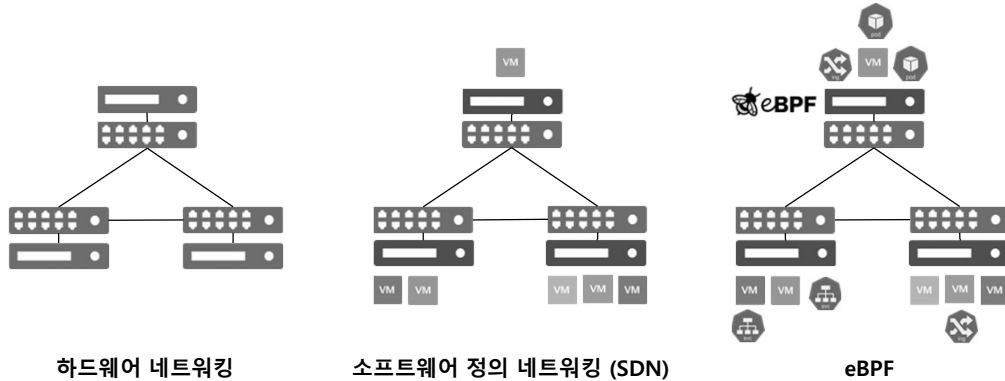
❖ Swagger(예): Generate Server Stubs & Client SDKs in SwaggerHub



Source: <https://swagger.io/tools/swagger-codegen/>, Swagger is the most widely used tooling ecosystem for developing APIs with the OpenAPI Specification (OAS).

III. '클라우드 서비스'

- ❖ 클라우드 네이티브 화(化) 하드웨어/소프트웨어 고려
 - 가상화 네트워크 가속(예) 'eBPF': 프로그램을 bpf() 시스템 콜을 통해서 linux 커널에 전달하면, 해당 내용을 커널 안의 샌드박스 형태의 인터프리터—JVM 처럼 다른 프로그램을 실행시켜주는 VM으로 동작
 - 클라우드 자원 연결(예) 'Cilium': Docker 및 Kubernetes와 같은 Linux 컨테이너 관리 플랫폼을 사용하여 배포된 응용 프로그램 서비스 간의 네트워크 연결을 보호하는 오픈 소스 소프트웨어



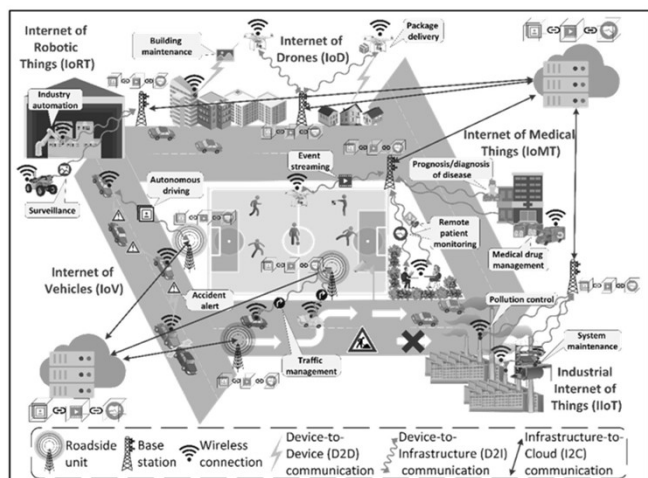
하드웨어 네트워킹

소프트웨어 정의 네트워킹 (SDN)

eBPF

III. '클라우드 서비스'

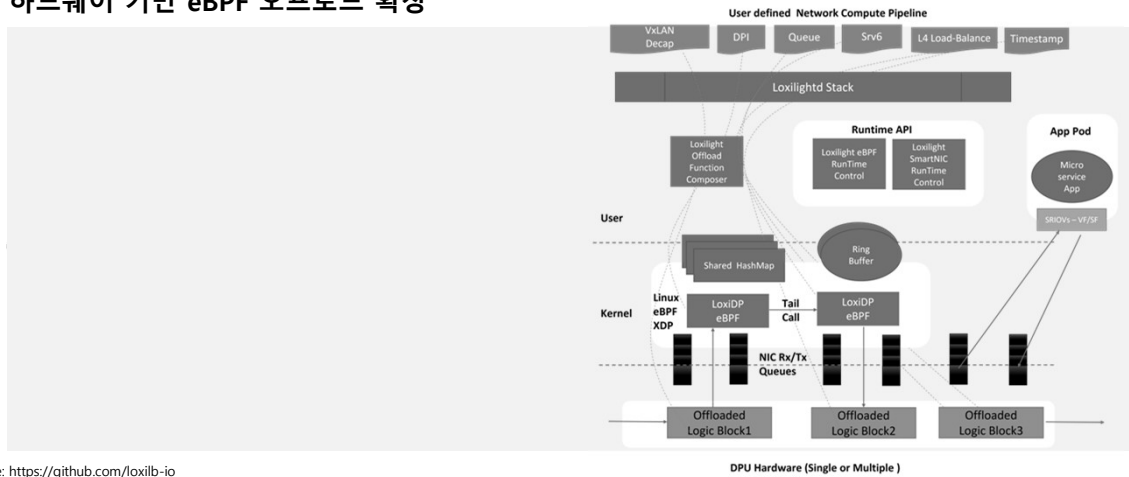
❖ Artificial Intelligence Applications and Self-Learning 6G Networks (for Smart City)



Source: https://www.mdpi.com/1424-8220/22/15/5750/html?fbclid=IwAR1XXKTpU2LF4_NG174K3cCzydONGsbU79OmcW1a37-WfaVfd6yU8SdPY8

III. '클라우드 서비스'

- ❖ eBPF (예): **LoxiLB** (오픈소스 Cloud Native 5G Edge LB)
- ❖ 하드웨어 기반 eBPF 오프로드 확장

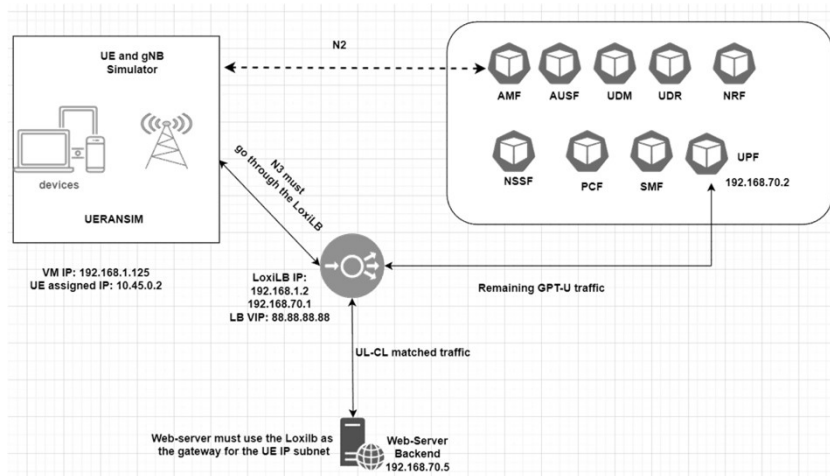


Source: <https://github.com/loxilb-io>

Source: <https://github.com/netlox-dev/loxilght-oss/blob/main/docs/design/architecture.md#loxilght-components>, Deprecated

III. '클라우드 서비스'

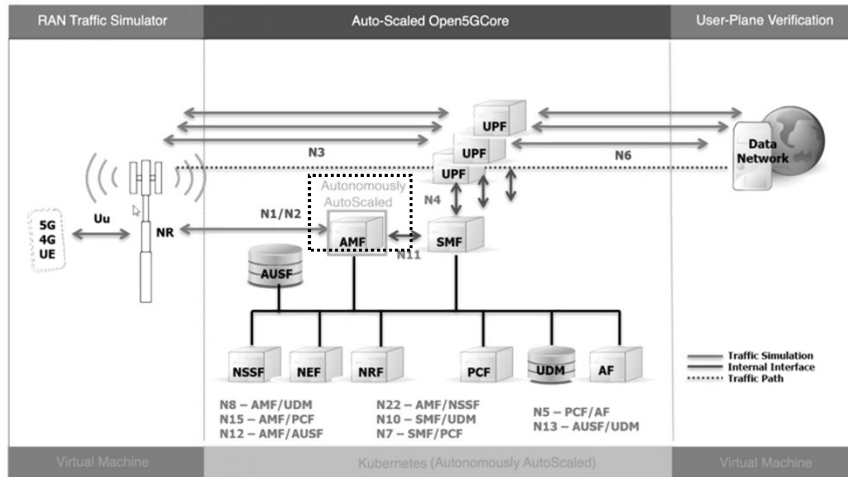
- ❖ **5G Uplink Classifier Using LoxiLB** (LoxiLB: 오픈소스 Cloud Native 5G Edge LB)



Source: <https://futureon.medium.com/5g-uplink-classifier-using-loxilb-7593a4d66f4c>

III. '클라우드 서비스'

❖ 5G control plane (CP) and 5G user plane (UP)



Source: (Anca Pavel, Fatih E. Nar, Federico Rossi, and Mathias Bogebrant, CC BY-SA 4.0)
Source: <https://www.redhat.com/architect/autoscale-5g-core>

III. '클라우드 서비스'

❖ 5G control plane (CP) and 5G user plane (UP)

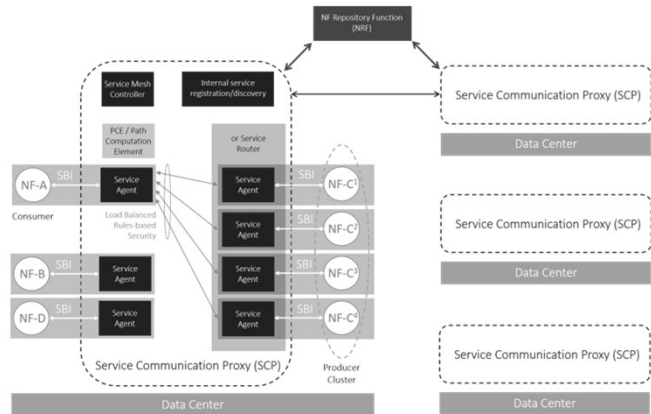
Source: Anca Pavel, Fatih E. Nar, Federico Rossi, and Mathias Bogebrant, CC BY-SA 4.0
Source: <https://www.redhat.com/architect/autoscale-5g-core>

III. '클라우드 서비스'

223

❖ 제조사 (예): Metaswitch

- A service mesh implementation employing the Service Communication Proxy (SCP)



Source: <https://www.metaswitch.com/blog/the-service-communication-proxy-5g-caught-up-in-a-service-mesh>

JS Lab

223

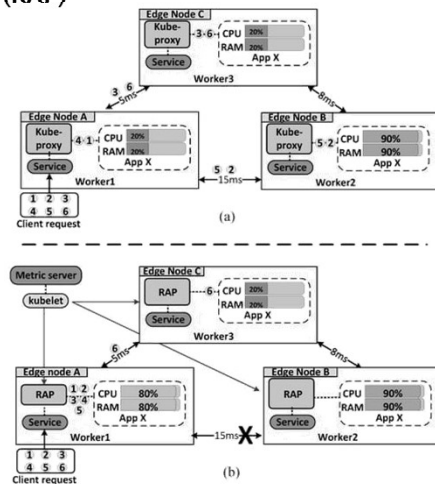
III. '클라우드 서비스'

224

❖ Load-Balancing of Kubernetes-Based Edge Computing Infrastructure

- Load-balancing algorithms using Resource Adaptive Proxy (RAP)

- Userspace
- RAP in K8s-based edge computing architecture.



Source: <https://www.mdpi.com/1424-8220/22/8/2869/htm>

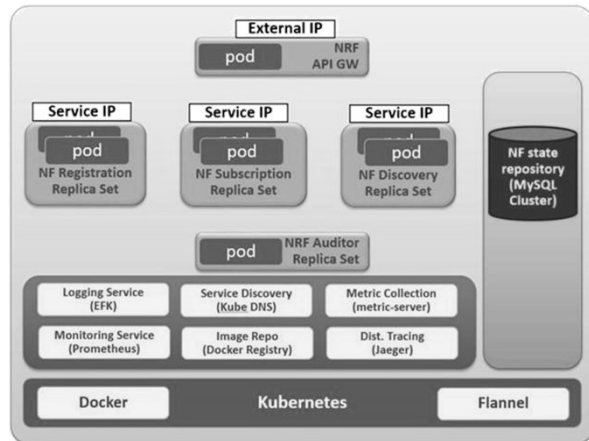
JS Lab

224

III. '클라우드 서비스'

225

- ❖ 제조사의 NRF (예): Oracle Communications Network Repository Function (OCNRF) Architecture
 - OCNRF Architecture Diagram



Source: https://docs.oracle.com/communications/F21625_01/docs.10/NRF%20User%27s%20Guide/GUID-72930D10-8817-4F82-83C2-695FC4B5589B.htm

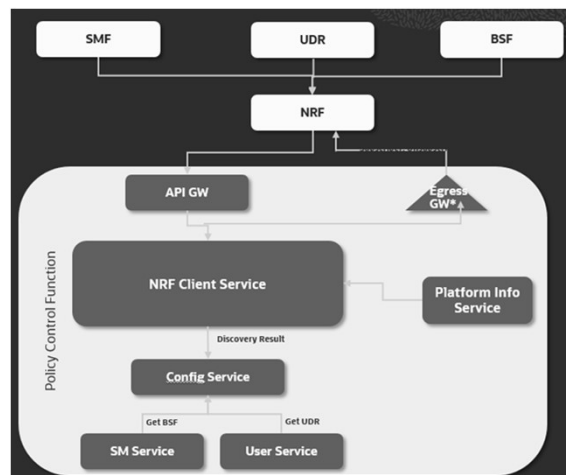
JS Lab

225

III. '클라우드 서비스'

226

- ❖ 제조사의 NRF (예): Integrating Cloud Native Core Policy with Different Network Functions
 - NRF Integration



Source: https://docs.oracle.com/en/industries/communications/cloud-native-core/2.3.0/policy_user_guide/integrating-cnc-policy-different-nfs.html

JS Lab

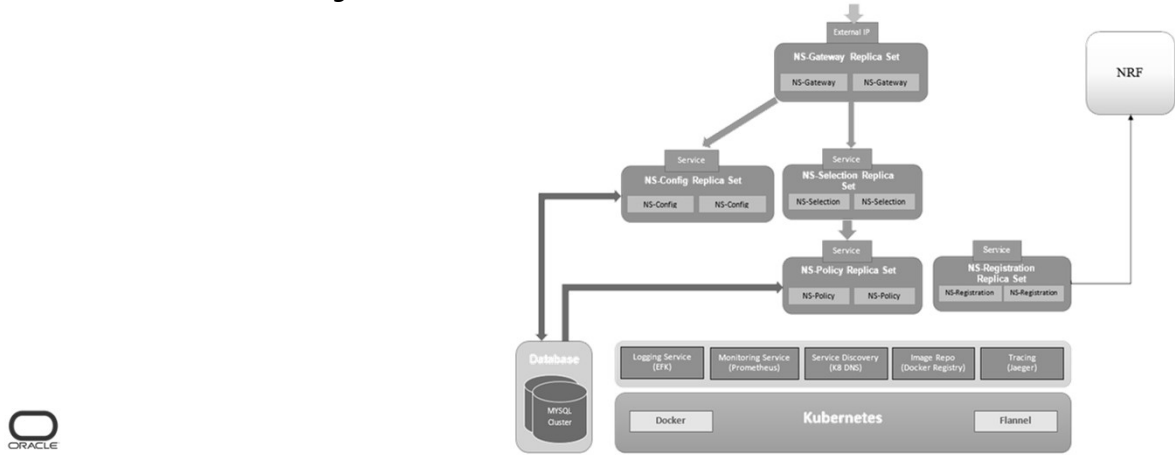
226

III. '클라우드 서비스'

227

❖ 제조사의 NSSF (예): Oracle NSSF Architecture

- OCNRF Architecture Diagram



비교/참고: 부록5. 제조사 NRF (1 of 2)
Source: https://docs.oracle.com/cd/F17999_01/docs/10/NSSF/GUID-959A11C4-687A-4AD3-AC5B-4372D40D3033.htm

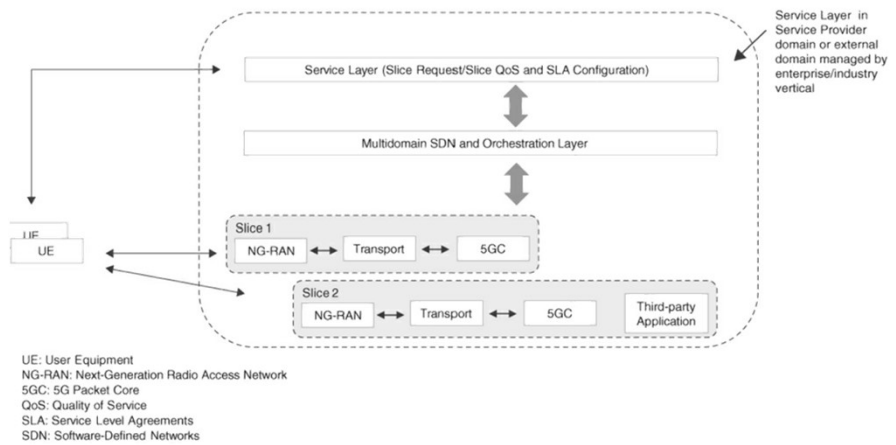
JS Lab

227

III. '클라우드 서비스'

228

❖ Multiple Domains Within a Network Slice Deployment



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

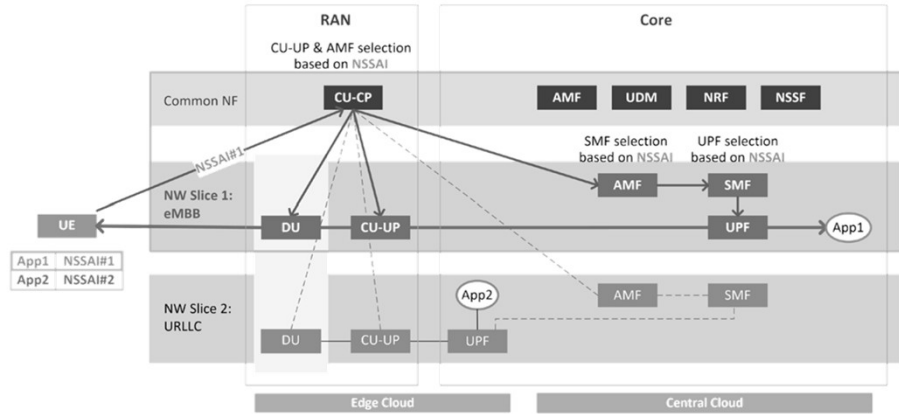
JS Lab

228

III. '클라우드 서비스'

❖ 제조사 (예): Cloud Native Architecture

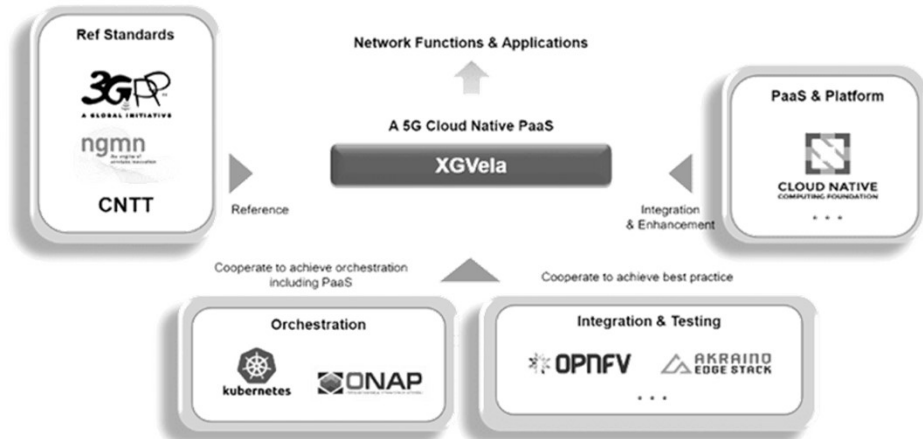
- Samsung: Network Slice Allocation to UE



Source: <https://images.samsung.com/is/content/samsung/p5/global/business/networks/insights/white-paper/5g-core-vision/5G-Core-Vision-Samsung-5G-Core-Vol.1.pdf>

III. '클라우드 서비스'

❖ Cloud Native Telco PaaS



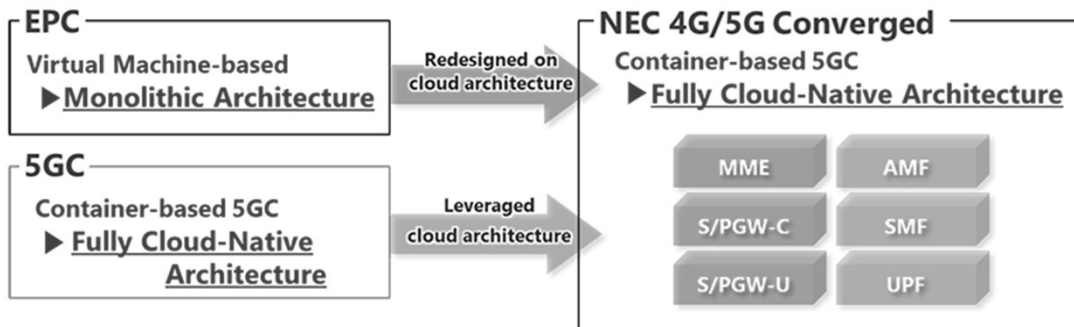
Source: <https://www.calsoftinc.com/blogs/2020/12/xgvela-bring-more-power-to-5g-with-cloud-native-telco-paas.html>

III. '클라우드 서비스'

231

❖ 제조사 (예): Cloud Native Architecture

- NEC: NEC's Cloud-Native Converged Core Reaches General Availability



Source: https://www.nec.com/en/press/202202/global_20220222_03.html

JS Lab

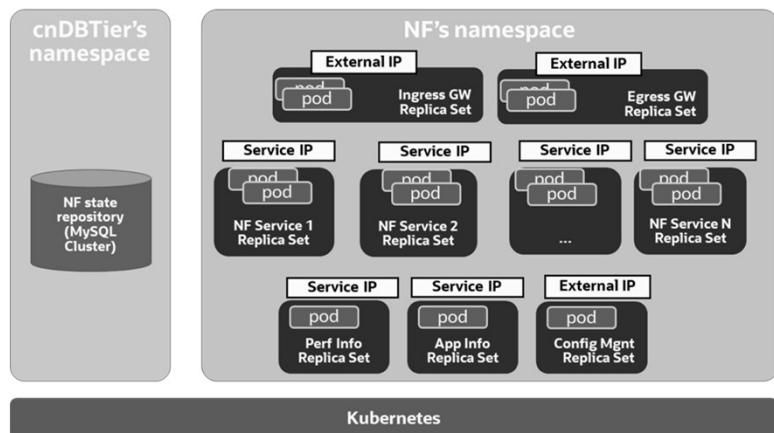
231

III. '클라우드 서비스'

232

❖ NF deployment on the cloud infrastructure

- the NF architecture with different microservices:



Source: <https://infohub.delltechnologies.com//dell-technologies-5g-core-validated-design-with-oracle-and-vmware-reference-architecture-guide-1/nf-deployment-on-the-cloud-infrastructure-1>

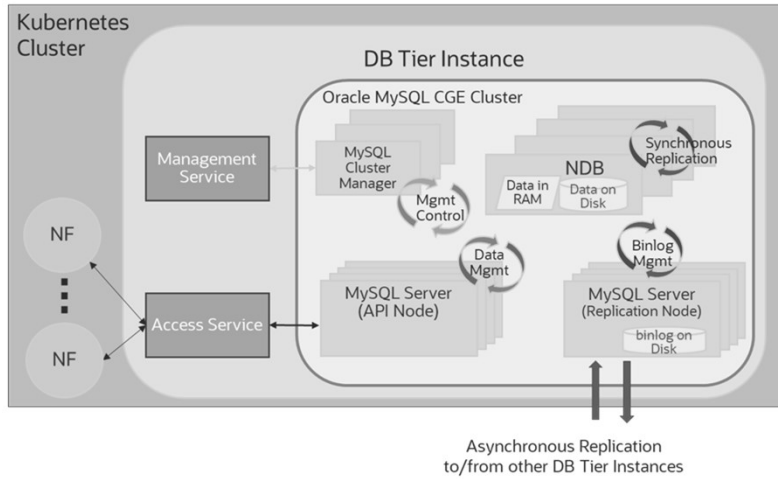
JS Lab

232

III. '클라우드 서비스'

❖ NF deployment on the cloud infrastructure

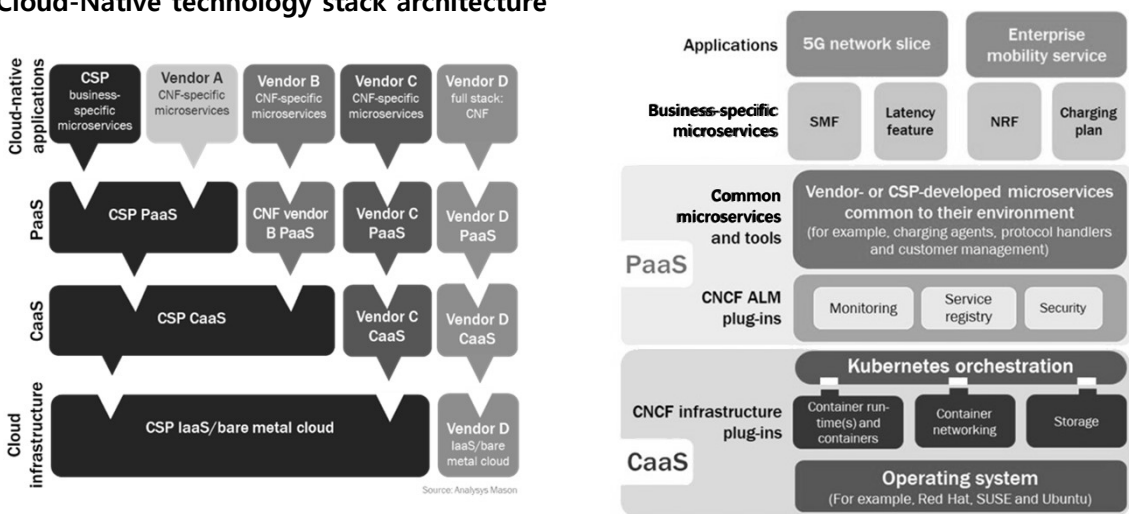
- cnDBTier architecture:



Source: <https://infohub.delltechnologies.com/!dell-technologies-5g-core-validated-design-with-oracle-and-vmware-reference-architecture-guide-1/nf-deployment-on-the-cloud-infrastructure-1>

III. '클라우드 서비스'

❖ Cloud-Native technology stack architecture



Source: <https://www.analysismason.com/research/content/articles/kubernetes-5g-application-rma16/>

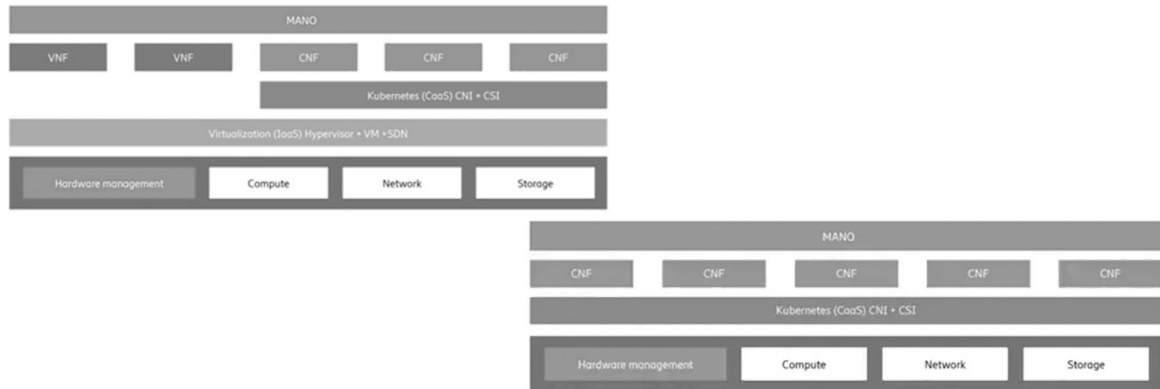
Source: Analysis Mason

III. '클라우드 서비스'

235

❖ 5G implications in the cloud infrastructure

- Option 1, adding CaaS on top of the VIM to the current NFVI
- Option 2, Run CNFs over CaaS on bare metal



Source: <https://www.ericsson.com/en/blog/2020/10/guide-to-building-cloudnative-infrastructure>

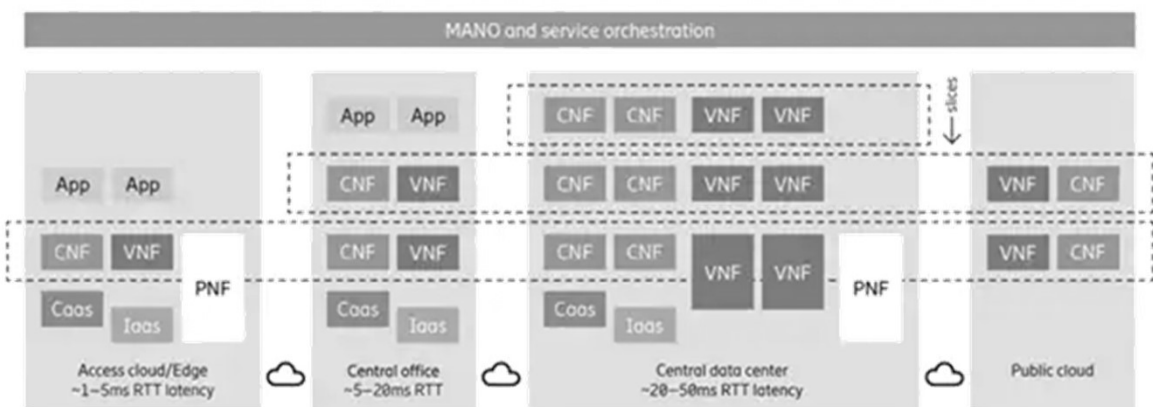
JS Lab

235

III. '클라우드 서비스'

236

❖ 5G implications in the cloud infrastructure



Source: <https://www.ericsson.com/en/blog/2020/10/guide-to-building-cloudnative-infrastructure>

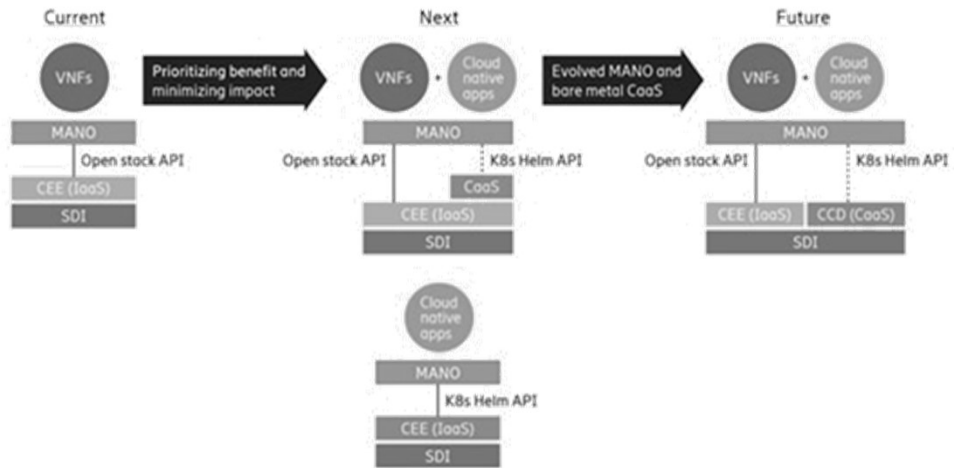
JS Lab

236

III. '클라우드 서비스'

237

❖ 제조사 (예): Ericsson - Cloud native transformation journey and deployment options



Source: <https://www.ericsson.com/en/blog/2020/10/guide-to-building-cloudnative-infrastructure>



JS Lab

237

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

238

- 모니터링
- 네트워크 슬라이싱
- Zero-touch Automation

◆ ◆ ◆ ◆ james@jslab.kr

JS Lab

238

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

239

❖ When we experience problems in development or production, we resort to debugging, logging and monitoring tools to find the root cause of the problem. Some of the tools which we should be familiar with are:

- strace
- SAR (System Activity Reporter)
- tcpdump
- GDB (GNU Project Debugger)
- syslog
- Nagios
- Zabbix.

MSA 수준
로그와 모니터링

마이크로서비스가 생성한 요청과
응답에 관한 정보를 저장하여 오류
시 필요 정보 제공

참고: 부록6. System Monitoring Software

strace: <https://strace.io/> SAR (System Activity Reporter): <https://www.linode.com/docs/guides/how-to-use-sar>



JS Lab

239

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

240

❖ K8s Logging / Alert (예)

The screenshot shows two parts of the K8s monitoring interface. The top part is the 'Cluster Alerts' page, which displays a table of active alerts. The bottom part is the 'Cluster Logging' configuration page, showing options for logging drivers like Elasticsearch, Splunk, Falco, Syslog, and Fluentd.

State	Name	Target	Condition	Notifiers
Active	A high number of leader chan...	Metric	Greater Than 3	Not Configured
Active	Database usage close to the q...	Metric	Greater Than 524288000	Not Configured
Active	Etcd is unavailable	System Service	Unhealthy	Not Configured
Active	Etcd member has no leader	Metric	Not Equal 1	Not Configured
Active	Controller Manager is unavaila...	System Service	Unhealthy	Not Configured
Active	Scheduler is unavailable	System Service	Unhealthy	Not Configured

JS Lab

240

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

241

❖ We can use the same tools on bare metal and VMs, but containers bring interesting challenges:

- Containers are ephemeral, so, when they die, all the metadata (e.g. logs) gets deleted as well, unless we store it in some other location.
- Containers do not have kernel space components. Check
- We want to have a container's footprint as low as possible. Installing debugging and monitoring tools increases the footprint size.
- Collecting per container statistics, debugging information individually and then analyzing data from multiple containers is a tedious process.

Ephemeral (일시적인)

JS Lab

241

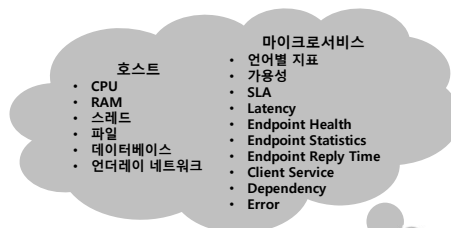
IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

242

❖ Below are some of the tools which we can use for containerized applications:

- **Debugging:** Docker CLI, Sysdig
- **Logging:** Docker CLI, Docker Logging Driver
- **Monitoring:** Docker CLI, Sysdig, cAdvisor/Heapster, Prometheus, Datadog, New Reli

모니터링
주요 지표



JS Lab

242

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

243

❖ Native Docker Features for Debugging

• Debugging:

1. docker inspect
2. docker logs

• Logging:

1. docker logs
2. Docker Logging Drivers: With the logging driver we can choose a Docker daemon wide or per container logging policy. Depending on the policy, Docker forwards the logs to the corresponding drivers. Docker supports the following drivers: jsonfile, syslog, journald, gelf (Graylog Extended Log Format), fluentd, awslogs, splunk. Once the logs are saved in a central location, we can use the respective tools to get the insights.

• Monitoring:

1. docker stats
2. docker top



JS Lab

243

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

244

❖ Sysdig provides an on-cloud and on-premise platform for container security, monitoring and forensics. According to sysdig.com, sysdig is

- "strace + tcpdump + htop + iftop + lsof + awesome sauce".



JS Lab

244

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

245

- ❖ It has two open source tools along with their paid enterprise class offerings.
 - **Sysdig:** It saves low-level system information from the running Linux instance, on which we can apply filters and do further analysis.
 - **Sysdig Monitor:** It is a paid offering that provides additional features on top of the open source version.
 - **Sysdig Falco:** It is a container-native tool which can help us gain visibility of containers and applications down to the finest details. It can collect information at system, network and file level. With rule-sets, we can provide our container security information and then take action based on them. For example, if a container does not satisfy the security requirements, Falco can kill the container, notify someone, etc.
 - **Sysdig Secure:** It is also a paid offering that provides additional features on top of the open source version.



JS Lab

245

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

246

- ❖ Features of Sysdig Tools
 - Sysdig tools have native support to many applications, infrastructure and container technologies, including Docker, Kubernetes, Mesos, AWS, and Google Cloud Platform.
 - Paid offerings provide alerting, dashboard, team management, etc.
 - They offer a programmatic interface with every part of Sysdig Monitor.



JS Lab

246

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

247

❖ Benefits of Sysdig Tools

- The tools capture low-level system information from the running Linux instance and containers.
- They offer native support for all Linux container technologies like Docker, LXC, etc.
- They are easy to install.
- They are built to run in production, minimizing performance overhead and the risk of crashes.
- They are Kubernetes-aware.



JS Lab

247

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

248

❖ cAdvisor

- cAdvisor (Container Advisor) is an open source tool to collect resource usage and performance characteristics for the host system and running containers. It collects, aggregates, processes, and exports information about running containers. As of now, it has native support for Docker and should also support other container runtimes out of the box.



JS Lab

248

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

249

❖ Using cAdvisor

- We can enable the cAdvisor tool to start collecting statistics with the following command:

```
sudo docker run \
  --volume=/:/rootfs:ro \
  --volume=/var/run:/var/run:rw \
  --volume=/sys:/sys:ro \
  --volume=/var/lib/docker/:/var/lib/docker:ro \
  --publish=8080:8080 \
  --detach=true \
  --name=cadvisor \
  google/cadvisor:latest
```

- and point the browser to http://host_IP:8080 to get the live statistics. cAdvisor exposes its raw and processed statistics via a versioned remote REST API. It also supports exporting statistics for InfluxDB. cAdvisor exposes container statistics as Prometheus metrics. Prometheus is an open source community-driven system and service monitoring toolkit.



JS Lab

249

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

250

❖ Heapster

- Heapster enables container cluster monitoring and performance analysis. It currently supports Kubernetes natively. Heapster collects and interprets various signals, like compute resource usage, lifecycle events, etc., and exports cluster metrics via REST endpoints. KubeDashboard, a performance analytics UI for Kubernetes, uses those endpoints.



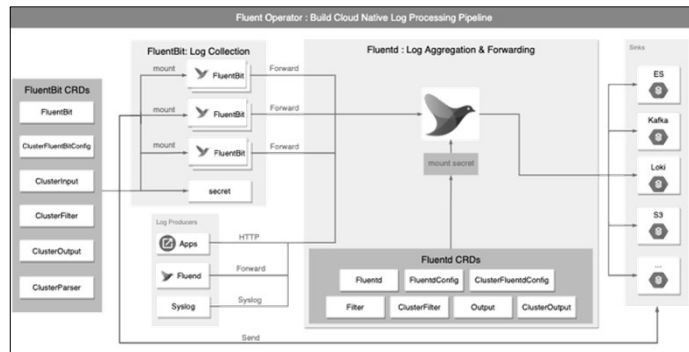
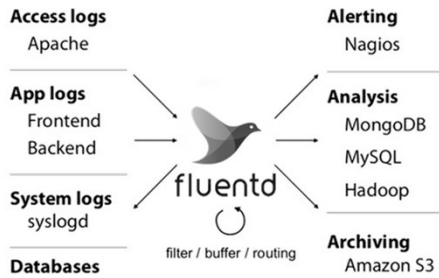
JS Lab

250

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

253

❖ Fluentd: an open source data collector for unified logging layer.



Source: Fluentd Architecture (by Treasure Data, Inc., retrieved from <https://docs.fluentd.org/>.)

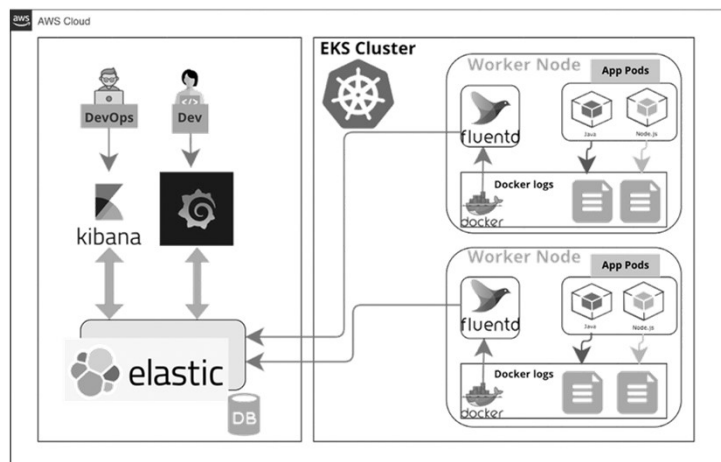
JS Lab

253

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

254

❖ Kubernetes application logging using Fluentd



Source: <https://faun.pub/kubernetes-application-logging-using-fluentd-2794c0ce9d24>

JS Lab

254

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

255

❖ Benefits of Using Fluentd

- It is an open source data collector.
- It is simple, fast, and flexible.
- It is performant and developer-friendly.



JS Lab

255

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

256

❖ Datadog

❖ Datadog provides monitoring and analytics as a service for Development and OPs teams. Some of the systems, applications and services it connects to are:

- Amazon EC2
- Apache
- Java
- MySQL
- CentOS.

INFRASTRUCTURE	APM	DIGITAL EXPERIENCE
Infrastructure Monitoring	Distributed Tracing	Real User Monitoring
Network Performance Monitoring	Continuous Profiler	Synthetic Monitoring
Network Device Monitoring	Database Monitoring	Continuous Testing
Container Monitoring	CI Visibility	Session Replay
Serverless	Service Catalog	Error Tracking
Cloud Cost Management	Universal Service Monitoring	PLATFORM CAPABILITIES
LOGS	SECURITY	CoScreen
Log Management	Cloud Security Management	Dashboards
Sensitive Data Scanner	Application Security Management	Watchdog
Audit Trail	Cloud SIEM	Alerts
Observability Pipelines		Incident Management
		Integrations
		API



Source: <https://www.datadoghq.com/>



JS Lab

256

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

257

❖ A detailed list of integration can be found in the documentation it provides. We need to install an agent in the host system, which sends the data to the Datadog's server. Once the data is sent, we can:

- Build an interactive dashboard.
- Search and co-relate matrices and events.
- Share the matrices and events.
- Get alerts.



JS Lab

257

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

258

❖ Docker Containers: Kubernetes Monitoring with Datadog

- The number of nodes in the cluster
- The running and stopped containers
- The most resource-consuming pods
- Docker logs, etc.



Source: Docker Containers - Kubernetes Monitoring with Datadog (by Datadog, Inc., retrieved from <https://www.acagroup.be/en/blog/monitor-kubernetes-cluster-datadog/>)



JS Lab

258

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

259

❖ Benefits of Using Datadog

- It comes pre-integrated with well-known third-party applications.
- It provides a seamless workflow, regardless of platform, location or language.
- It configures information filtration to get only needed metrics.
- It allows us to enable the system to send alerts or notifications when serious issues arise.
- It offers tools for team collaboration.
- It is scalable.



JS Lab

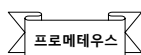
259

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

260

❖ Prometheus

- ❖ Prometheus is an open source tool used for system monitoring and alerting. It was originally developed by SoundCloud and is now one of the incubated projects at CNCF Foundation.
- ❖ Prometheus is suitable for recording any purely numeric time series data. It works well for both machine-centric monitoring like CPU, memory usage, and monitoring of highly dynamic service-oriented architectures. It is primarily written in Go.



다차원 시계열 데이터베이스로서
경고 문자와 그래프 계산을 지원



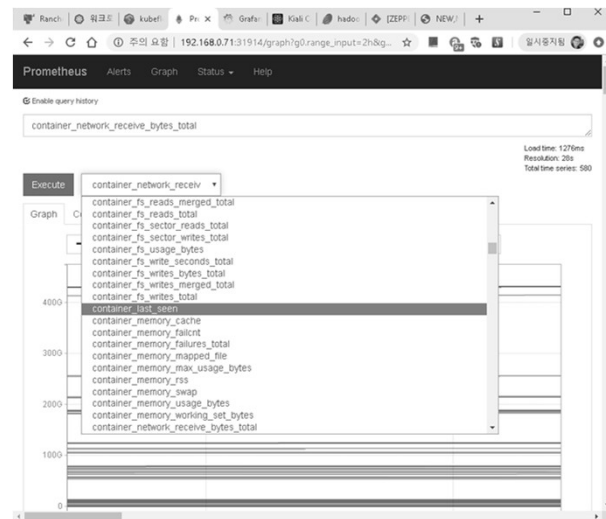
JS Lab

260

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

261

❖ Prometheus



JS Lab

261

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

262

❖ Prometheus Features

- It is very reliable.
- It supports multi-dimensional data model with time series data identified by metric name and key/value pairs.
- It supports a query language to effectively query the collected time series data.
- It support metrics collection through pull- and push-based mechanism.
- It can discover target endpoints via service discovery or static configuration.
- It can connect with external tools like Grafana and Pagerduty for dashboarding and alerting.
- It supports client libraries for programming language like Go, Java, Python, etc. to add instrumentation to their code.

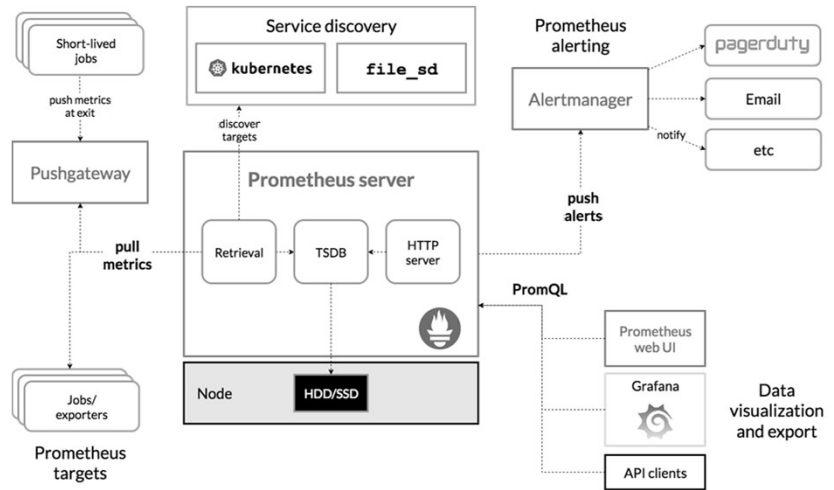


JS Lab

262

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

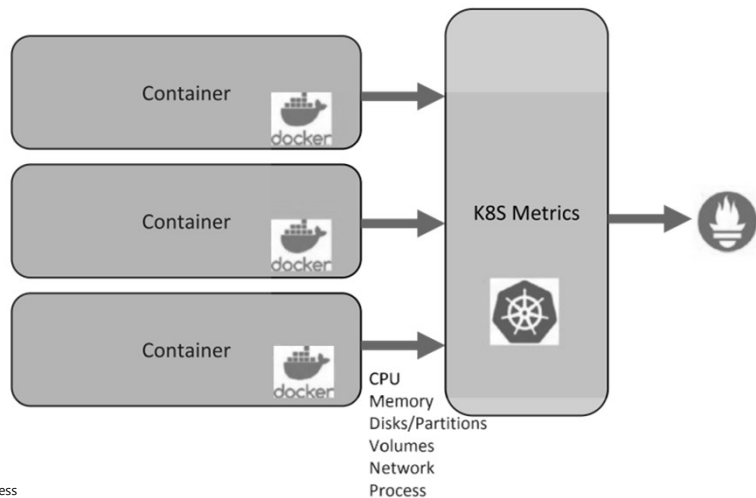
❖ Prometheus Architecture



Source: <https://prometheus.io/docs/introduction/overview/>

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ 컨테이너와 클러스터 모니터링 (Container and cluster monitoring)

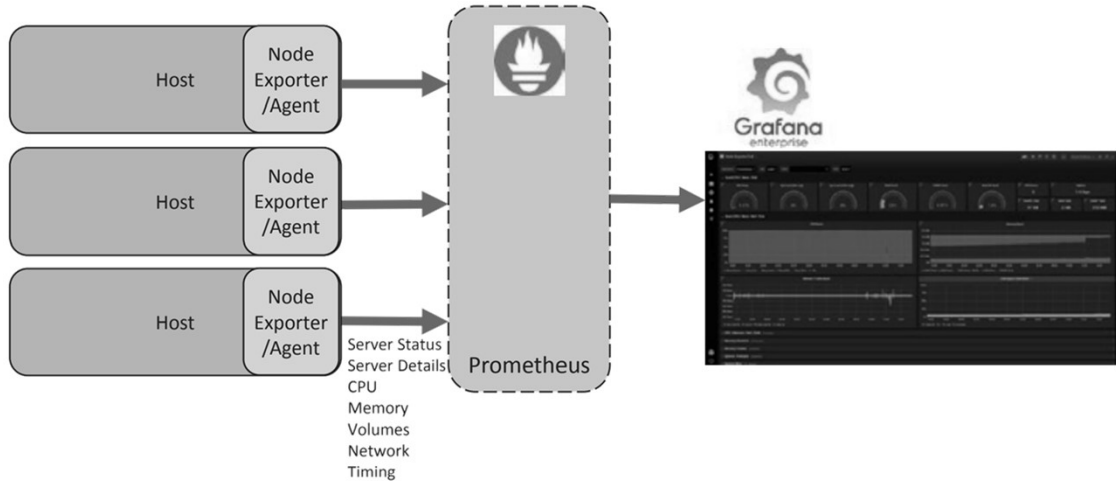


Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

265

❖ 호스트 수준 모니터링 (Host-level monitoring)



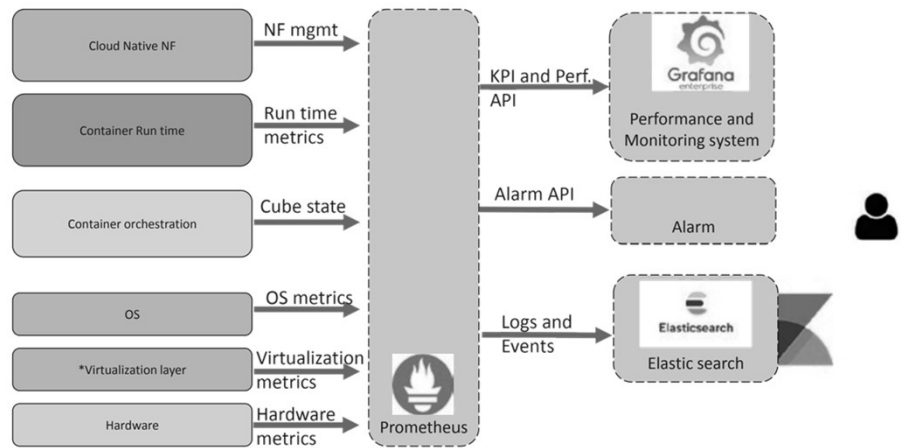
JS Lab

265

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

266

❖ 모니터링과 장애해결 (Illustration of monitoring and troubleshooting)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

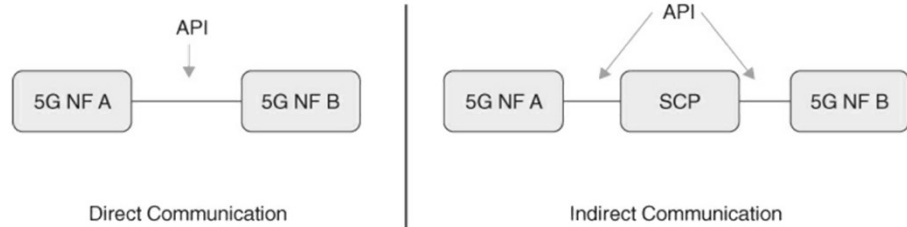
JS Lab

266

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

267

❖ Direct and Indirect Communication for NF and NF Services



5G NF: 5G Network Function
API: Application Programming Interface
SCP: Service Communication Proxy

Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.



JS Lab

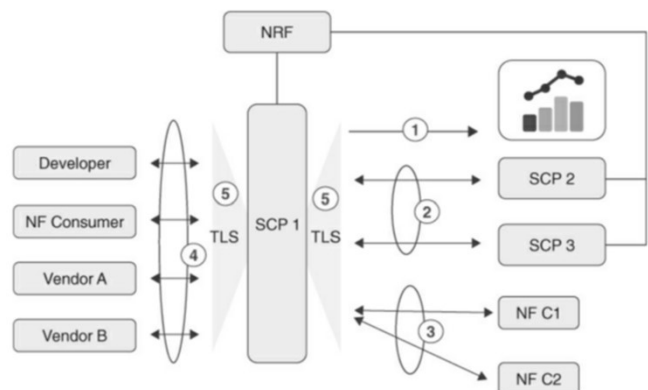
267

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

268

❖ Key Functions of SCP

- ① Centralized monitoring
- ② Distributed SCP deployment
- ③ Load balancing
- ④ Resilient integration with third-party vendors and application developers
- ⑤ Encrypted communications



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

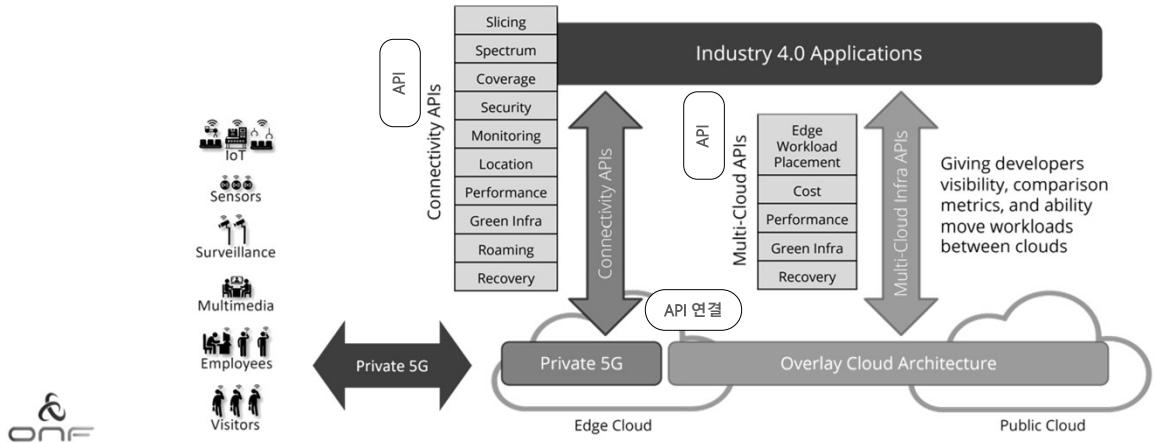


JS Lab

268

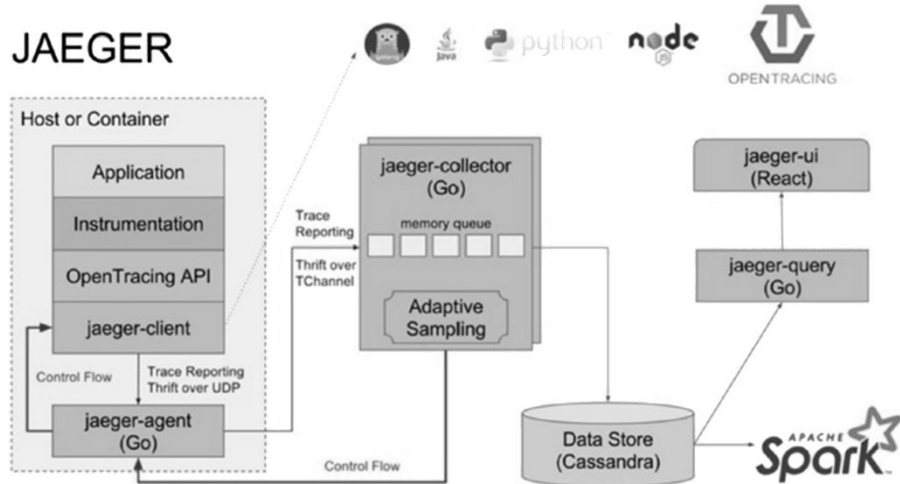
IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ IoT-5G-Edge Architecture (ONF)



IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

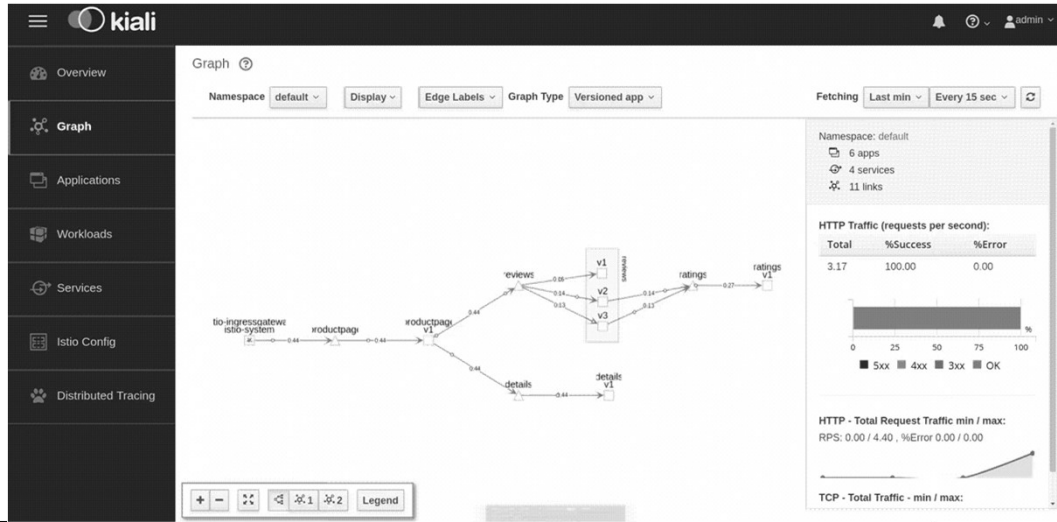
❖ 분산 트레이스 (Distributed tracing)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

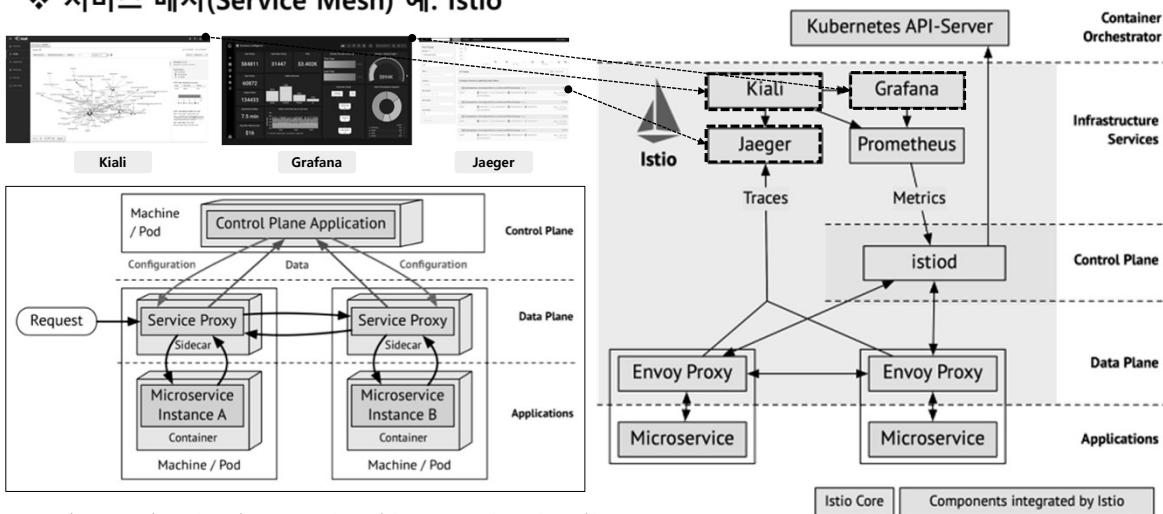
IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ Istio (Service Mesh)



IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ 서비스 메시(Service Mesh) 예: Istio



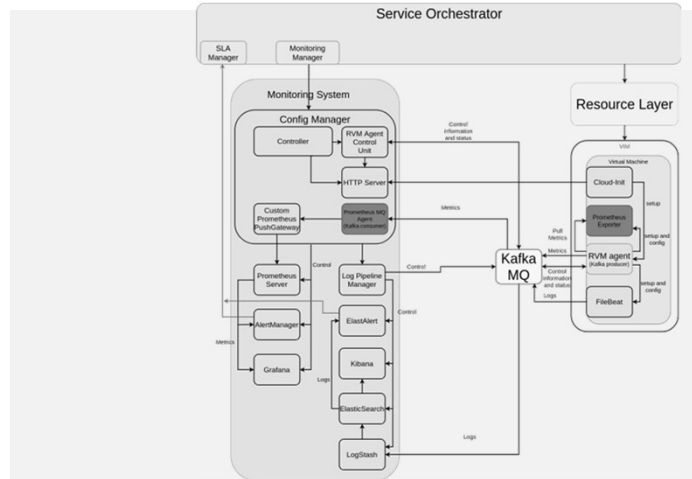
Istio Core Components integrated by Istio

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

273

❖ Vertical-oriented Monitoring System Architecture

- 서비스 오케스트레이터
- 프로메테우스 (Prometheus)
- 카프카 (Kafka Message Queue)



Source: 5GPPP Architecture Working Group, 5G Architecture White Paper

JS Lab

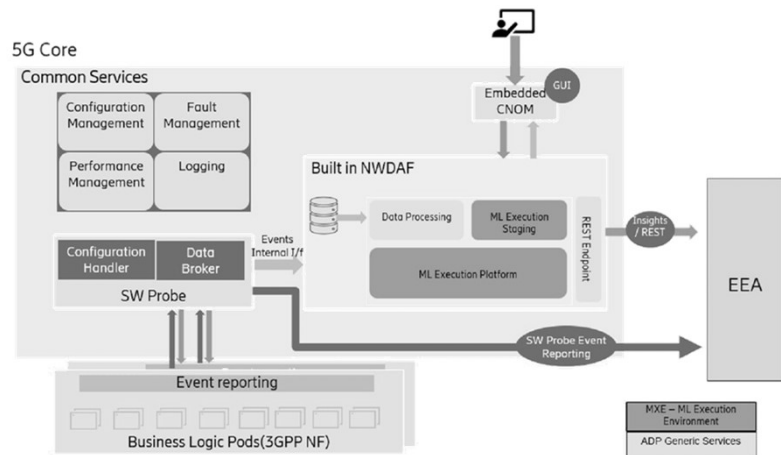
273

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

274

❖ 제조사 (예): Ericsson - To enable ML/AI platform that constitutes the NWDAF

- What built-in NWDAF looks like in 5G Core



Spirent

Source: <https://www.ericsson.com/en/blog/2021/11/enabling-smarter-networks-capitalizing-on-cloud-native-in-nwda-f-use-cases>

JS Lab

274

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

275

❖ Observability for Monitoring, Tracing Lineage in Microservices

• Four Pillars of Observability

- Log aggregation/analytics
- Alerting/visualization
- Distributed systems tracing infrastructure
- Monitoring



Source: https://www.decipherzone.com/blog-detail/observability-monitoring-in-microservices?fbclid=IwAR110yqe7k0mnectfUVUUpnYUelcVHOg_tqlf1NpSzUQGR3VfAxldbDNlvaY



JS Lab

275

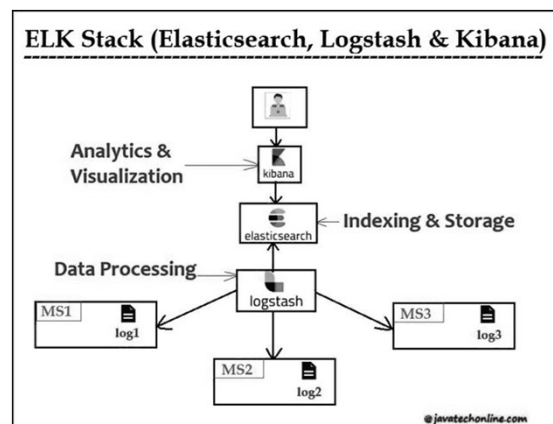
IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

276

❖ Monitor Java Spring Boot Microservices Application Using ELK Stack

• ELK Stack

- Elasticsearch
- Logstash
- Kibana



Source: https://javatechonline.com/how-to-monitor-spring-boot-microservices-using-elk-stack/?fbclid=IwAR2iqeO2oHKovoedVHH2FZP_G87SzxXUomFtjiaXrrhBb65pB3DTLkA-S4



JS Lab

276

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

277

❖ Observability Tools

- SigNoz
- Grafana Labs
- Honeycomb
- Instana
- Lightstep
- Dynatrace
- Datadog
- Splunk
- New Relic
- Sentry

Source: <https://www.mantisnet.com/blog/ebpf-v-sidecar-containers-5g-observability>



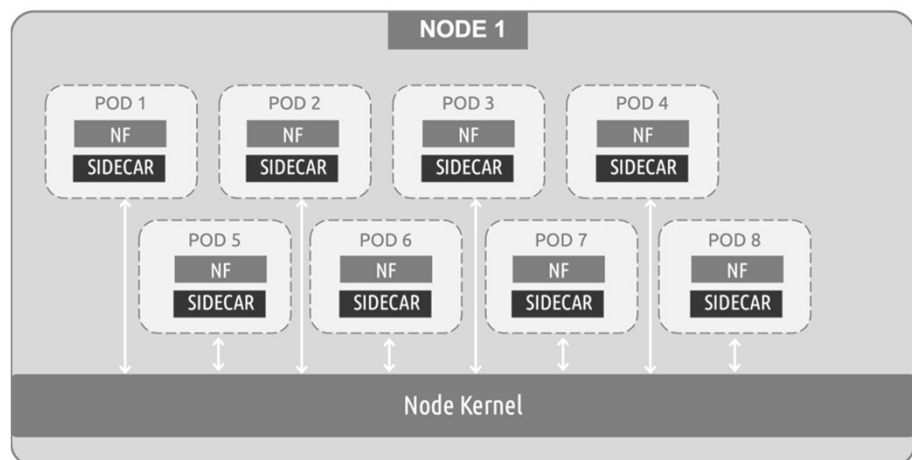
JS Lab

277

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

278

❖ The sidecar container



Source: <https://www.mantisnet.com/blog/ebpf-v-sidecar-containers-5g-observability>

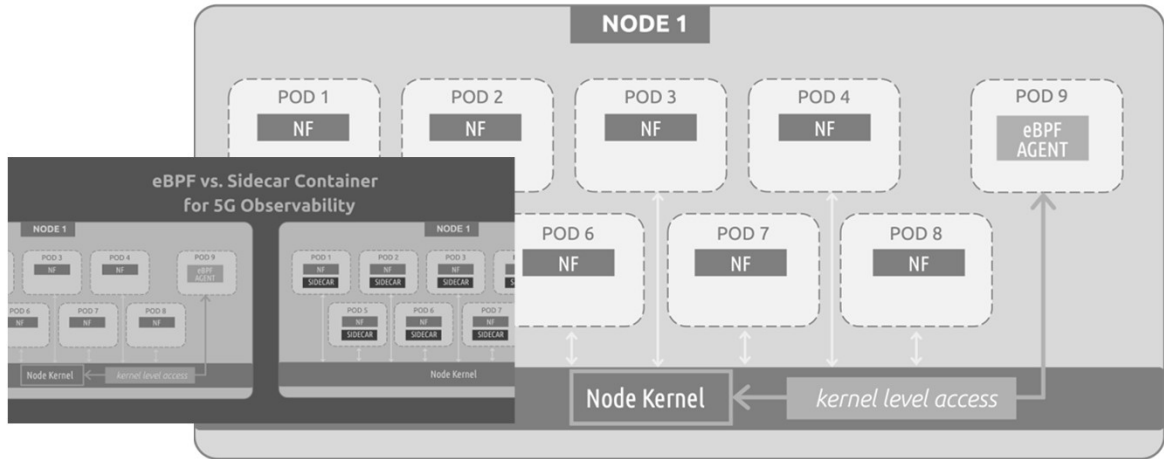


JS Lab

278

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

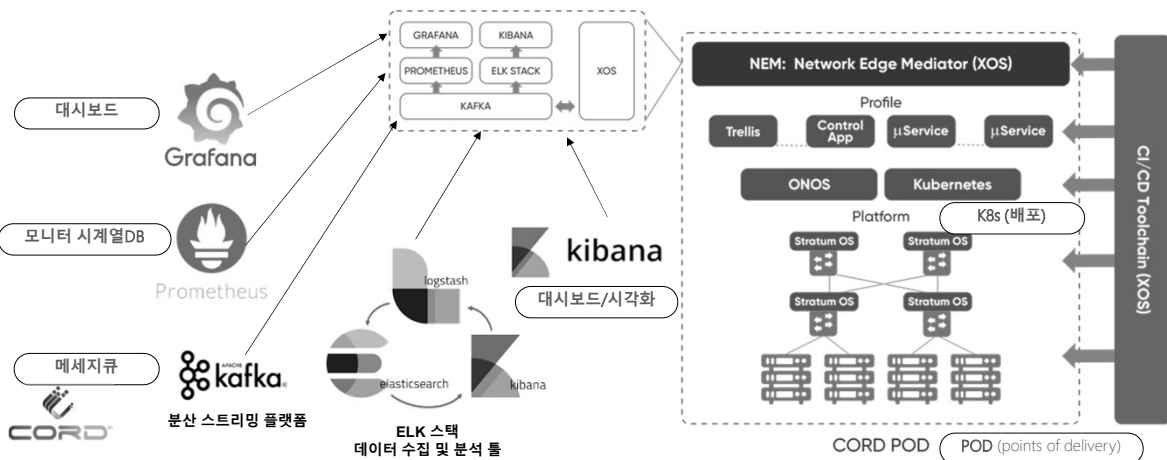
❖ eBPF technology



Source: <https://www.mantisnet.com/blog/ebpf-v-sidecar-containers-5g-observability>

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ CORD (Central Office Re-architected as a Datacenter)



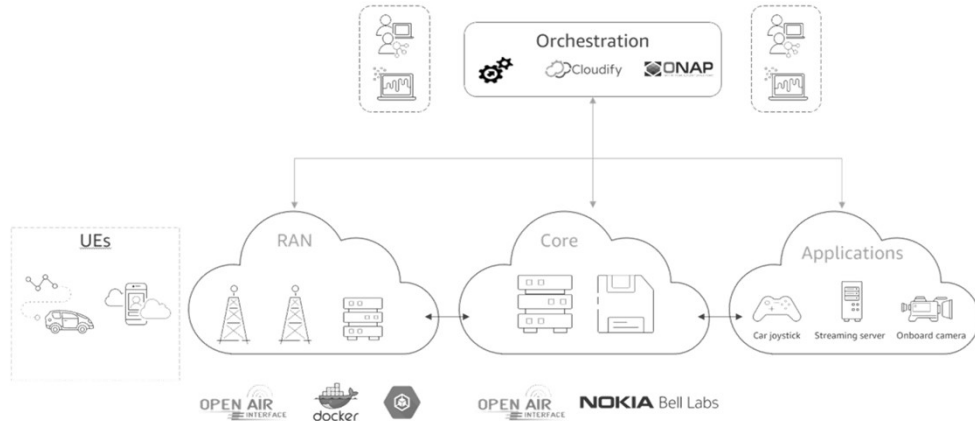
Source: <https://opennetworking.org/cord/>

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

281

❖ Implementing 5G Network Slicing with Cloudify on AWS

- Use of Cloudify with ONAP to deliver full 5G network slicing.



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>



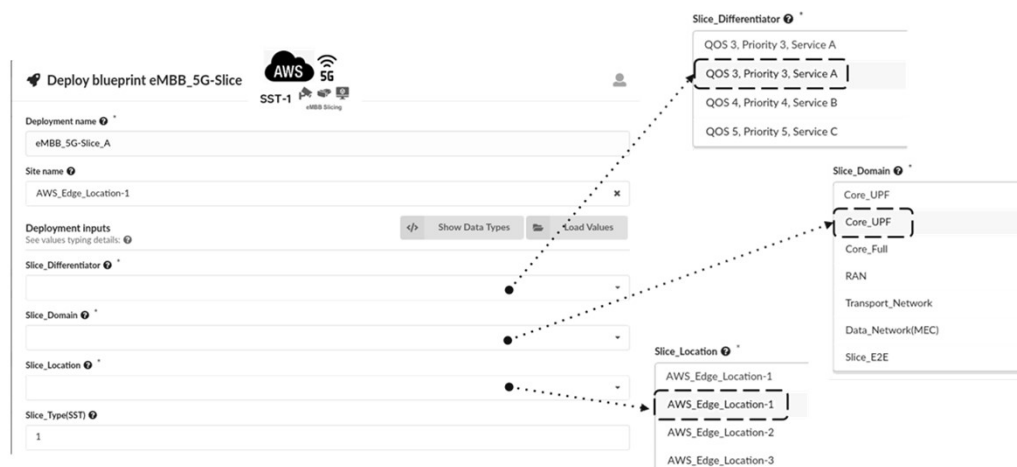
JS Lab

281

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

282

❖ Configuring a network slice.



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>



JS Lab

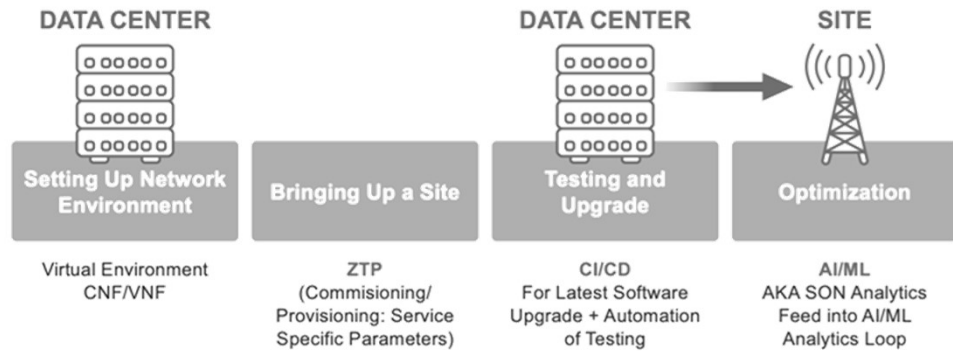
282

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

283

- ❖ 자동화: Network automation uses zero-touch positioning, CI/CD, and AI/ML to bring upgrades to the radio access network.

STAGES OF NETWORK TO AUTOMATE



CI/CD (Continuous Integration/Continuous Development)

Source: Parallel Wireless.

Source: <https://www.5gtechnologyworld.com/network-automation-takes-the-work-out-of-upgrades/>

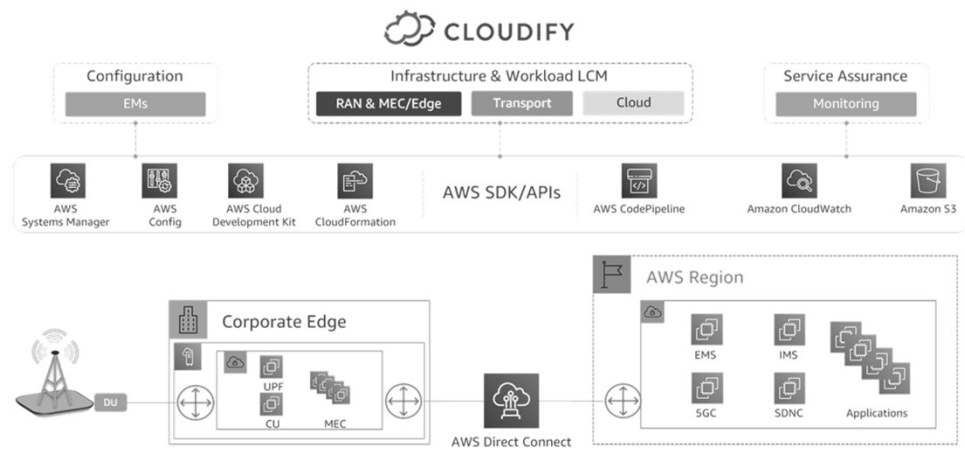
JS Lab

283

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

284

- ❖ Implementing 5G Network Slicing with Cloudify on AWS
 - Cloudify architecture on AWS.



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>

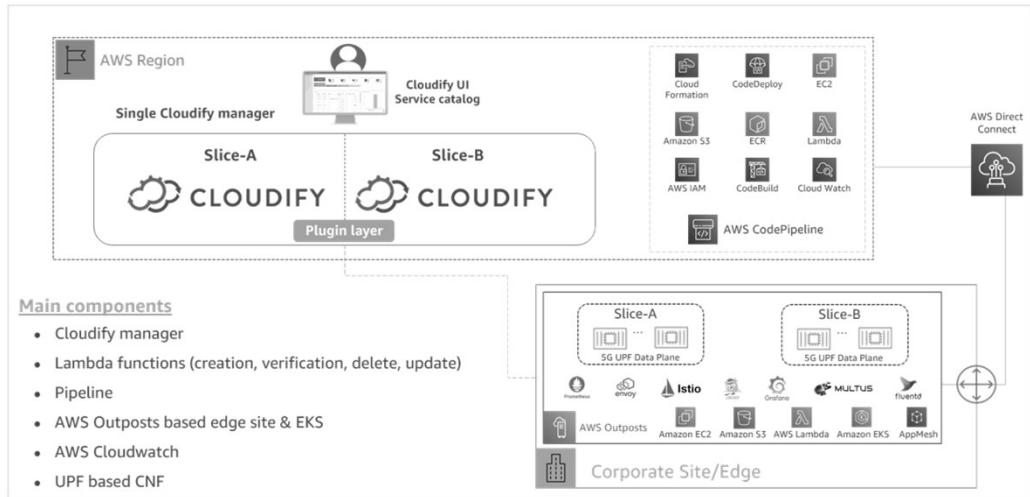
JS Lab

284

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

285

❖ Cloudify on AWS for network slicing



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>

JS Lab

285

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

286

❖ Manage network slices.

Deployment Name	Blueprint	Created	Creator	Node Instances (4)
uRLLC_5G-Slice	uRLLC_5G-Slice Site Name: AWS_Edge_Location-3	19-11-2020 15:38	admin	[Stop] [Refresh] [Check] [Delete]
mMTC_5G-Slice	mMTC_5G-Slice Site Name: AWS_Edge_Location-2	19-11-2020 15:37	admin	[Stop] [Refresh] [Check] [Delete]
eMBB_5G-Slice	eMBB_5G-Slice Site Name: AWS_Edge_Location-1	19-11-2020 14:55	admin	[Stop] [Refresh] [Check] [Delete]

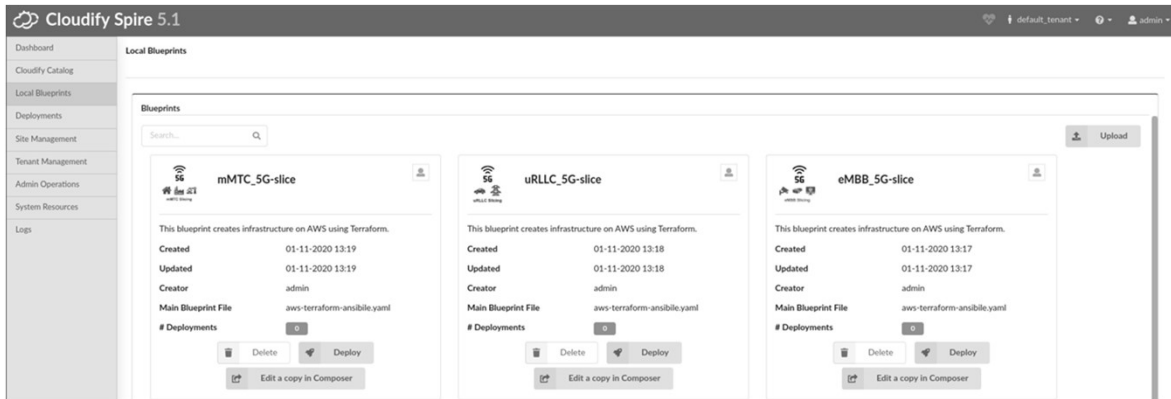
Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>

JS Lab

286

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

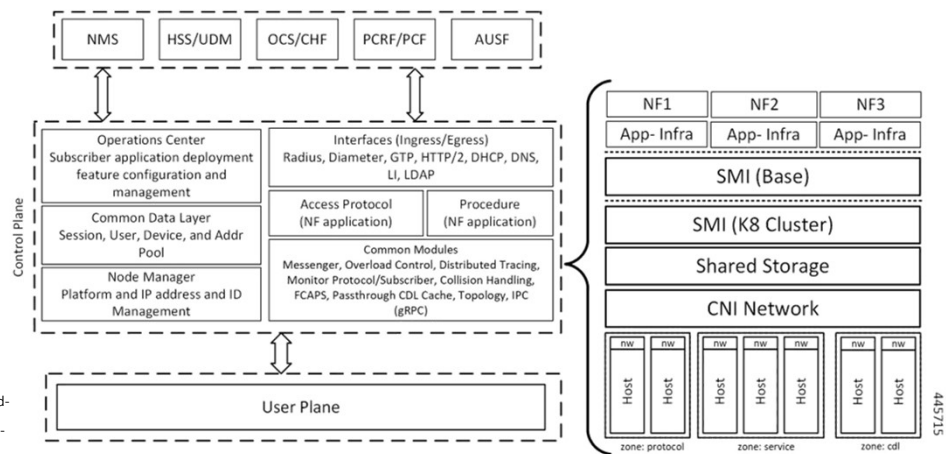
❖ Providing a simple operator interface using Cloudify catalog service.



Source: <https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/>

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

❖ 제조사(예): Cisco - Ultra Cloud Core CP Architectural Components



FCAPS (fault, configuration, accounting, performance, and security)

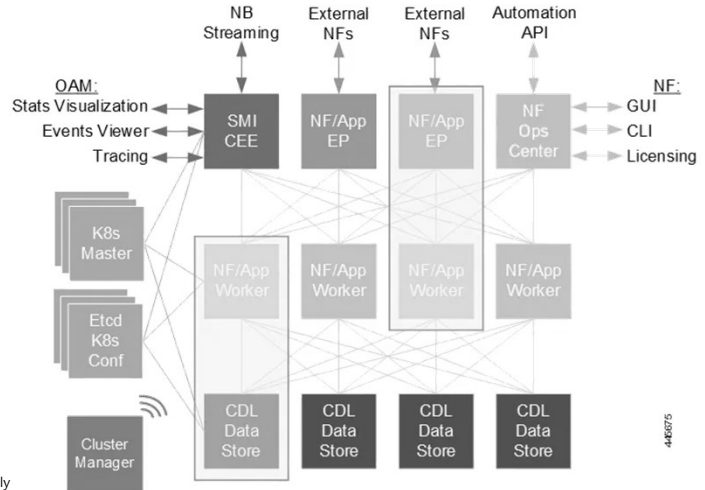
Cisco Smart Install (SMI) is a "plug-and-play" configuration and image-management feature that provides zero-touch deployment for new (typically access layer) switches.

Source: https://www.cisco.com/c/en/us/td/docs/wireless/ucc/upf/2020-03/b_ucc-5g-upf-config-and-admin-guide_2020-03/m.html

IV. '모니터/제어, 클라우드 네이티브 5G 네트워크'

289

❖ SMI Components



Cisco Smart Install (SMI) is a "plug-and-play" configuration and image-management feature that provides zero-touch deployment for new (typically access layer) switches.

Source: https://www.cisco.com/c/en/us/td/docs/wireless/ucc/upf/2020-03/b_ucc-5g-upf-config-and-admin-guide_2020-03/m.html

443075



JS Lab

289

V. '관리/보안'

290

- Private 5G Network 인프라 관리
- 통신 보안
- 제조사 솔루션
- Design Pattern

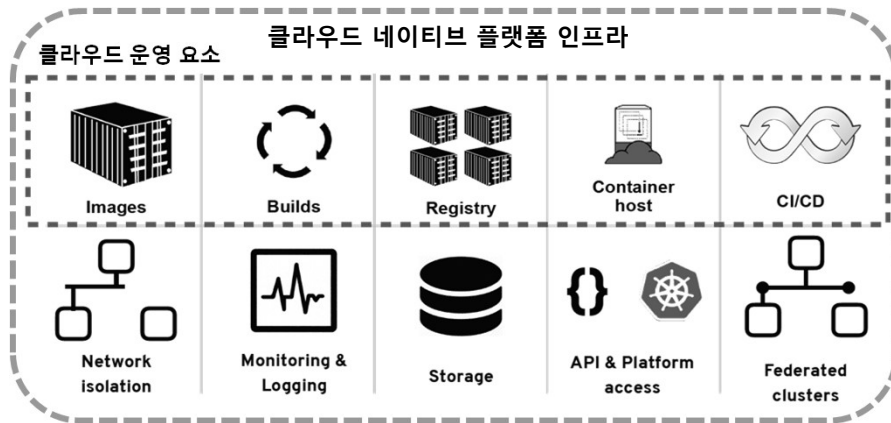
290

V. '관리/보안'

291

❖ 클라우드 인프라 구성 요소 고려 보안

- SDDC 추상화 운영 요소: 컴퓨팅, 스토리지, 네트워크, 관리, API 접속
- 클라우드 운영 요소: Images, Builds, Registry, Container Host, CI/CD



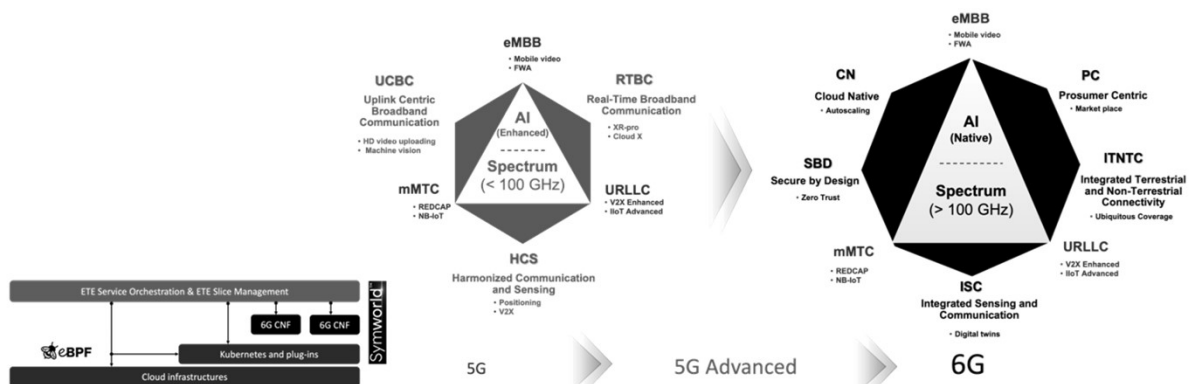
JS Lab

291

V. '관리/보안'

292

❖ Towards 6G Cloud Native and Secure by Design



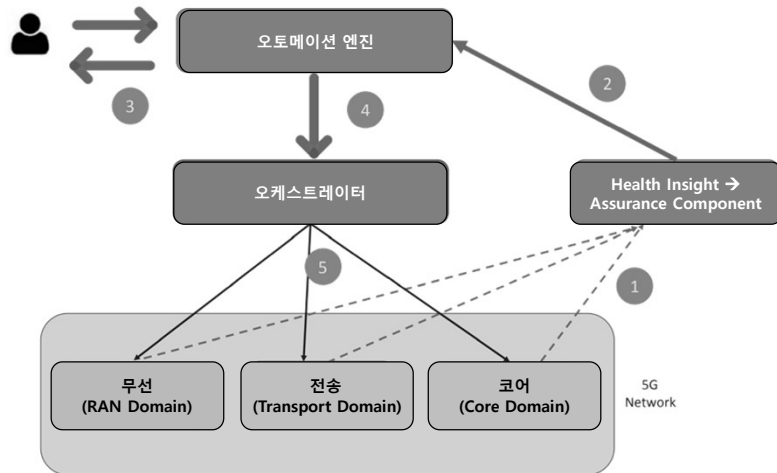
JS Lab

292

V. '관리/보안'

293

❖ Closed-loop automation with the help of service assurance



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

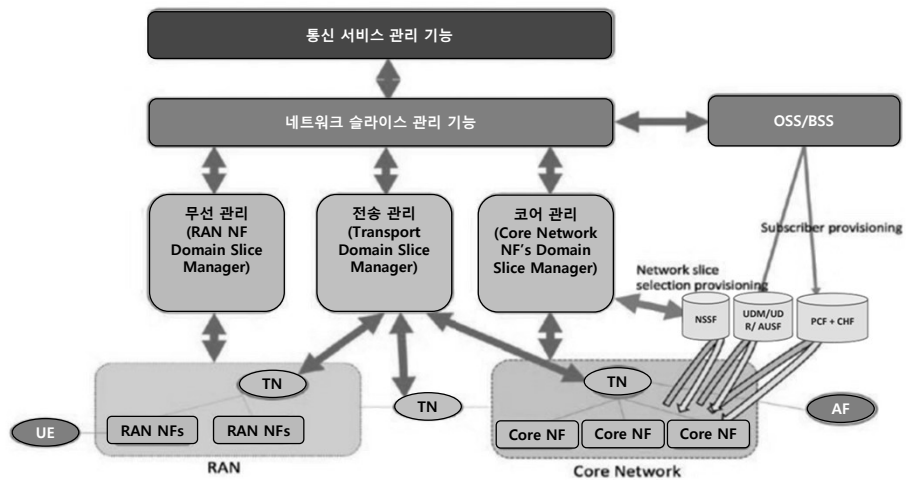
JS Lab

293

V. '관리/보안'

294

❖ End-to-end slice orchestration overview



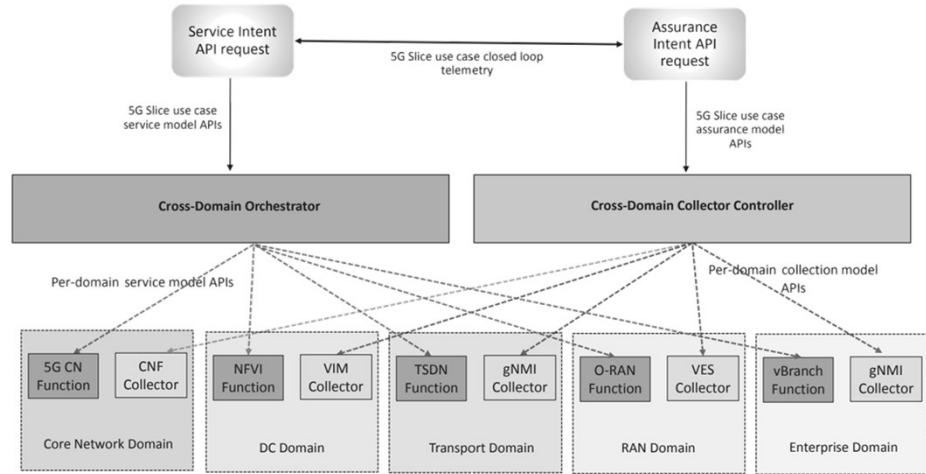
Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

JS Lab

294

V. '관리/보안'

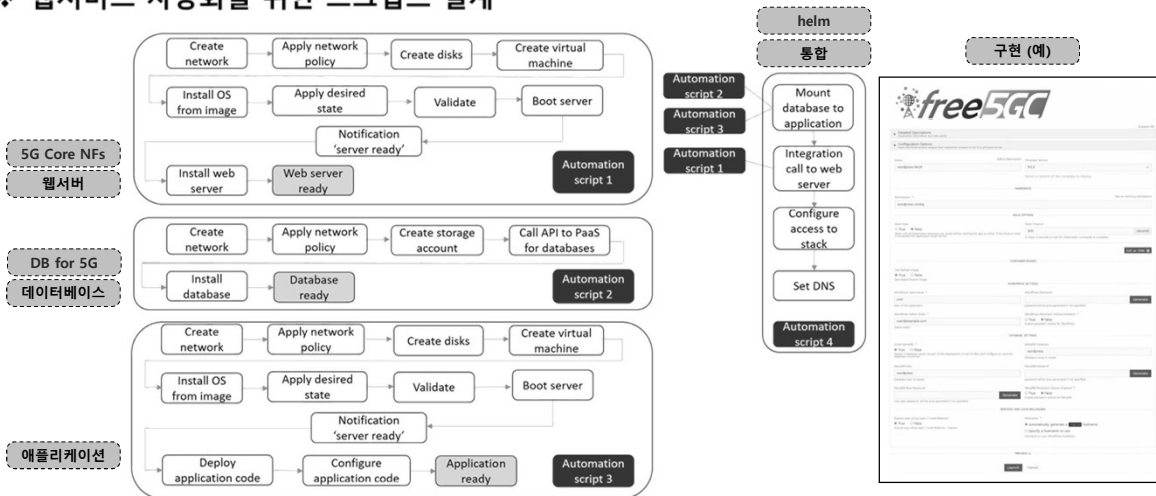
❖ 의도기반 모델링 개념 (Intent-based modeling concept)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

V. '관리/보안'

❖ 웹서비스 자동화를 위한 스크립트 설계



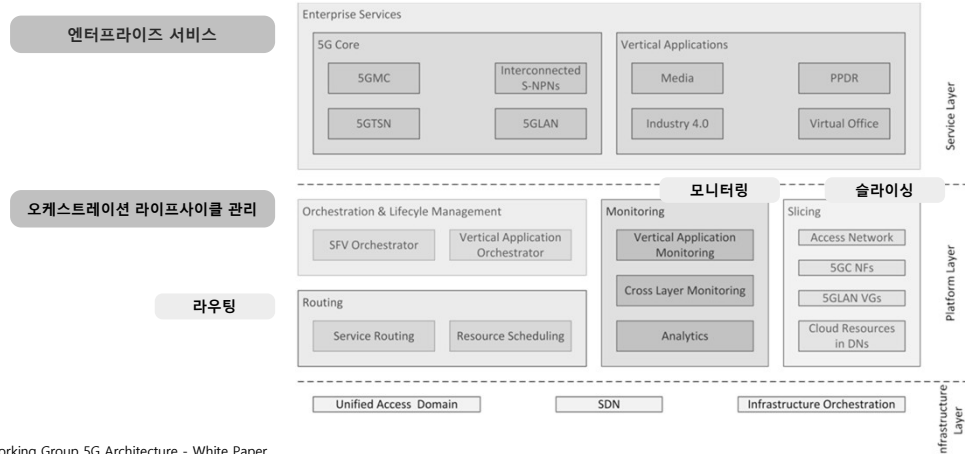
Source: Mulder, Jeroen. Multi-Cloud Architecture and Governance: Leverage Azure, AWS, GCP, and VMware vSphere to build effective multi-cloud solutions. Packet Publishing.

V. '관리/보안'

297

❖ 엔터프라이즈 서비스 고려

• High level system component overview of a disintegrated private network architecture



Source: 5GPPP Architecture Working Group 5G Architecture - White Paper

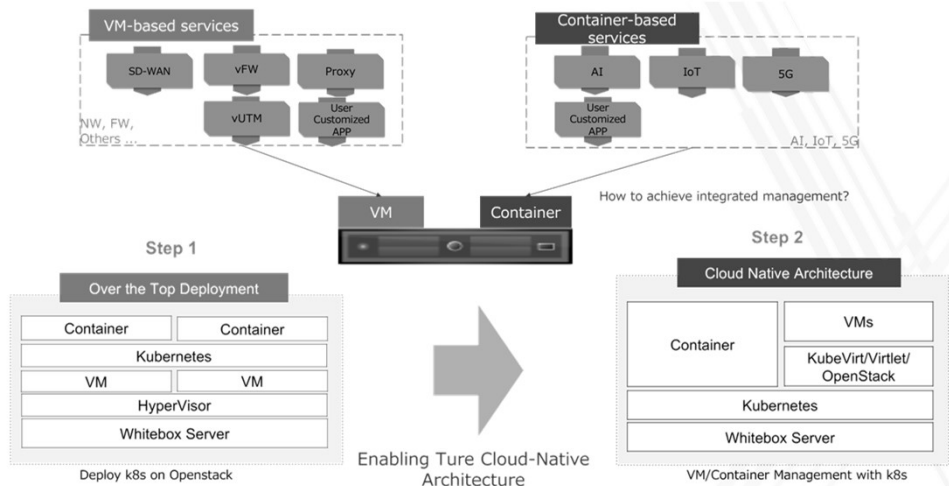
JS Lab

297

V. '관리/보안'

298

❖ Cloud Native Platform Architecture (예: NTT Communications Corporation)



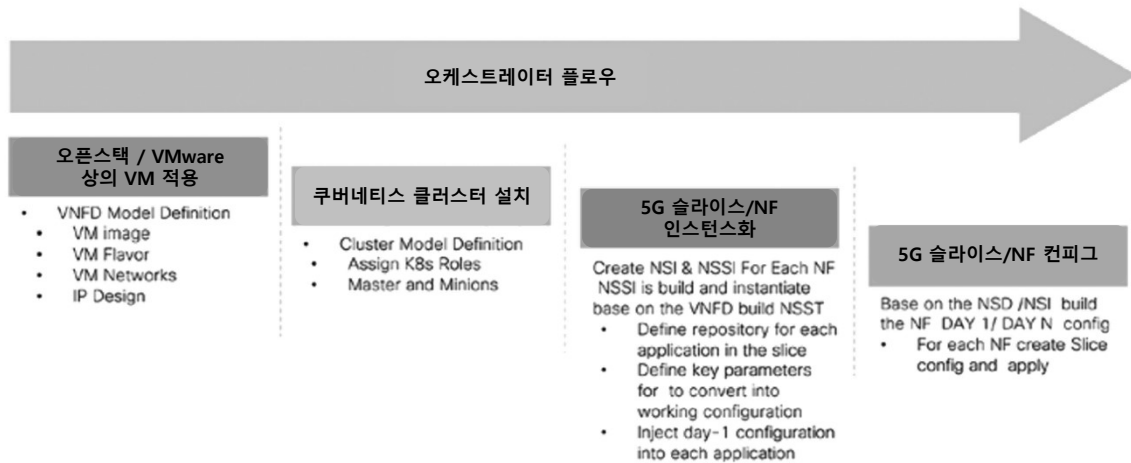
JS Lab

298

V. '관리/보안'

299

❖ 5G core NF and slice creation



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

JS Lab

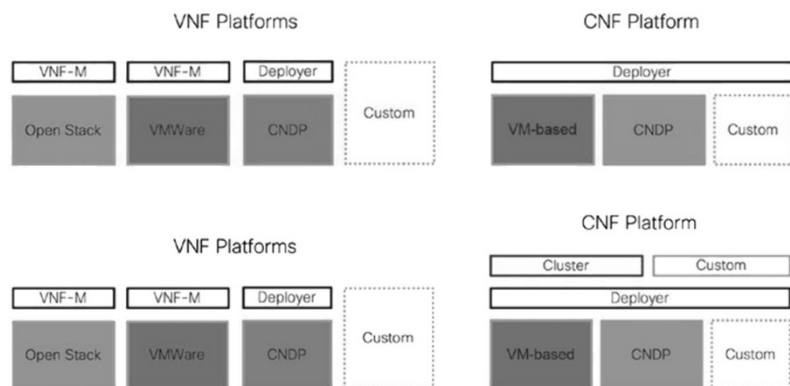
299

V. '관리/보안'

300

❖ Hybrid infrastructure with different platforms

❖ Deployment layer automations



critical node detection problem (CNDP)

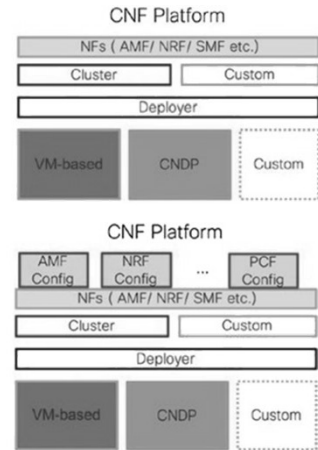
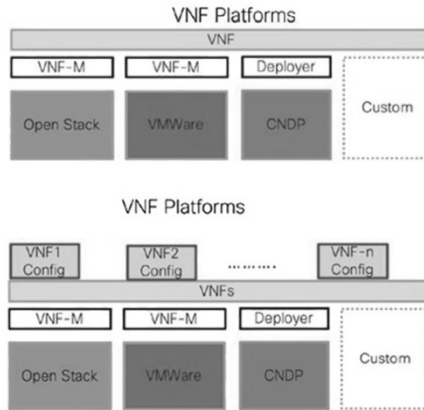
Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

JS Lab

300

V. '관리/보안'

- ❖ Function layer automation
- ❖ Configuration layer automation

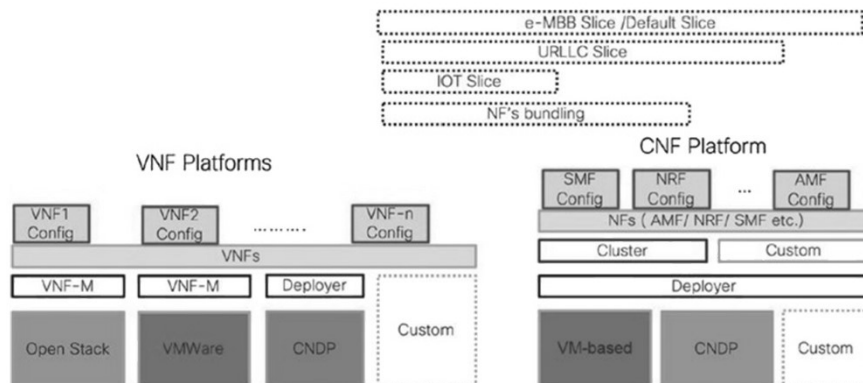


critical node detection problem (CNDP)
 Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress



V. '관리/보안'

- ❖ 5G abstraction



critical node detection problem (CNDP)
 Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

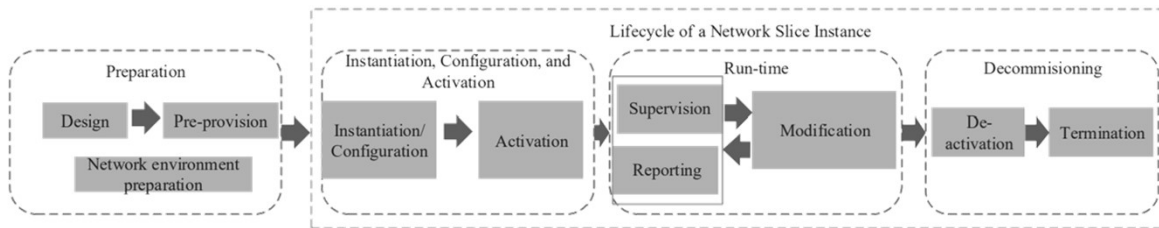


V. '관리/보안'

303

❖ 네트워크 슬라이스의 라이프사이클 관리: Lifecycle phases of a NSI > 3GPP spec 23.801

- Preparation
- Lifecycle of a Network Slice Instance
 - Instantiation, Configuration, and Activation
 - Run-time
 - Decommisioning



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

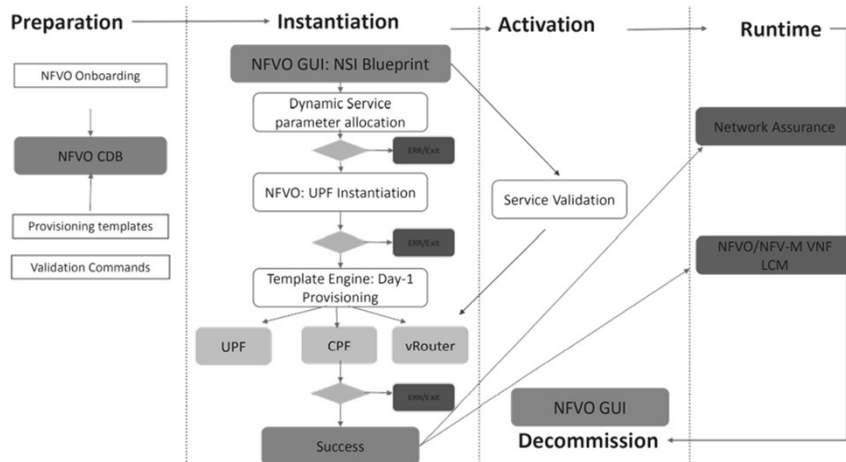
JS Lab

303

V. '관리/보안'

304

❖ UPF 슬라이스 라이프사이클: UPF slice lifecycle with core network domain slice orchestrator



critical node detection problem (CNDP)

Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

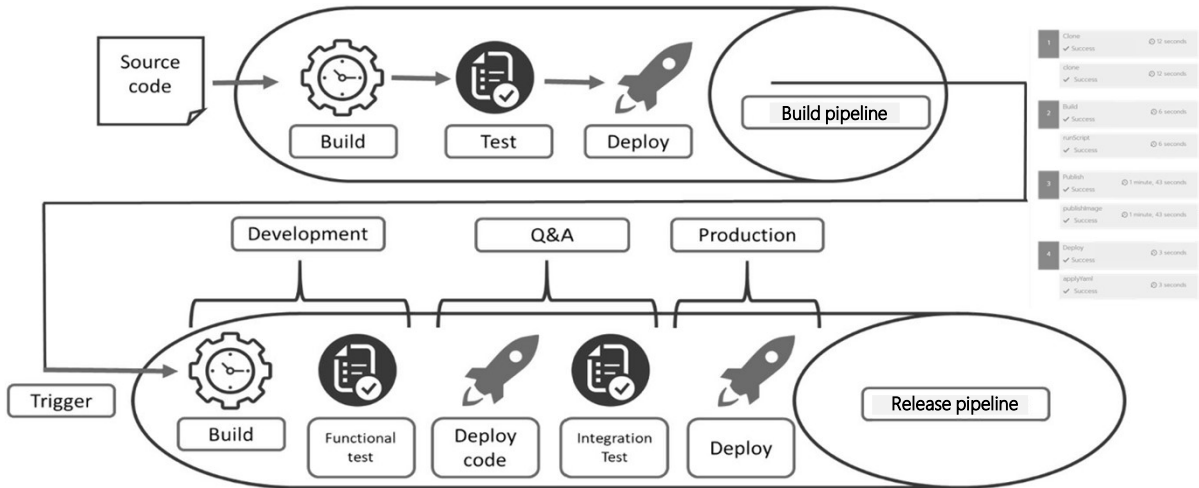
JS Lab

304

V. '관리/보안'

305

❖ Build / Release pipeline (구분)



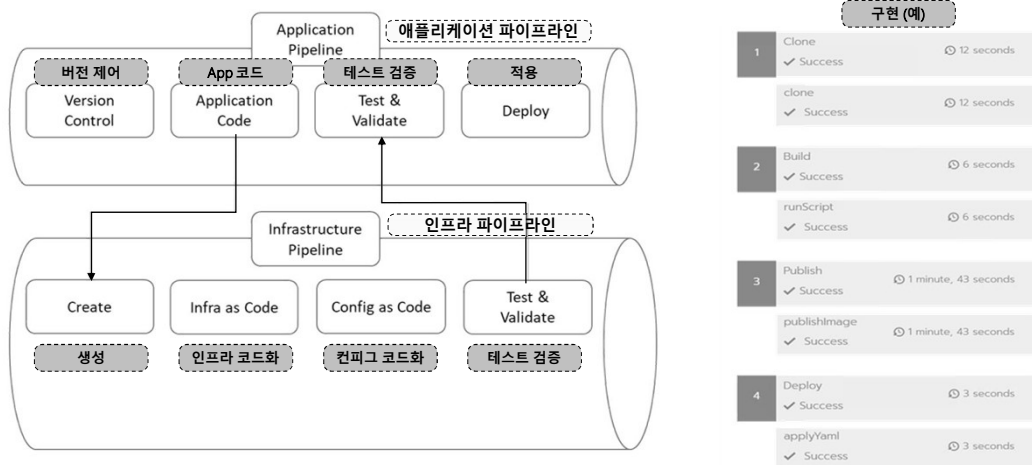
JS Lab

305

V. '관리/보안'

306

❖ 애플리케이션/인프라 (구분) - CI/CD 하이레벨 개념



Source: Mulder, Jeroen. Multi-Cloud Architecture and Governance: Leverage Azure, AWS, GCP, and VMware vSphere to build effective multi-cloud solutions. Packt Publishing.

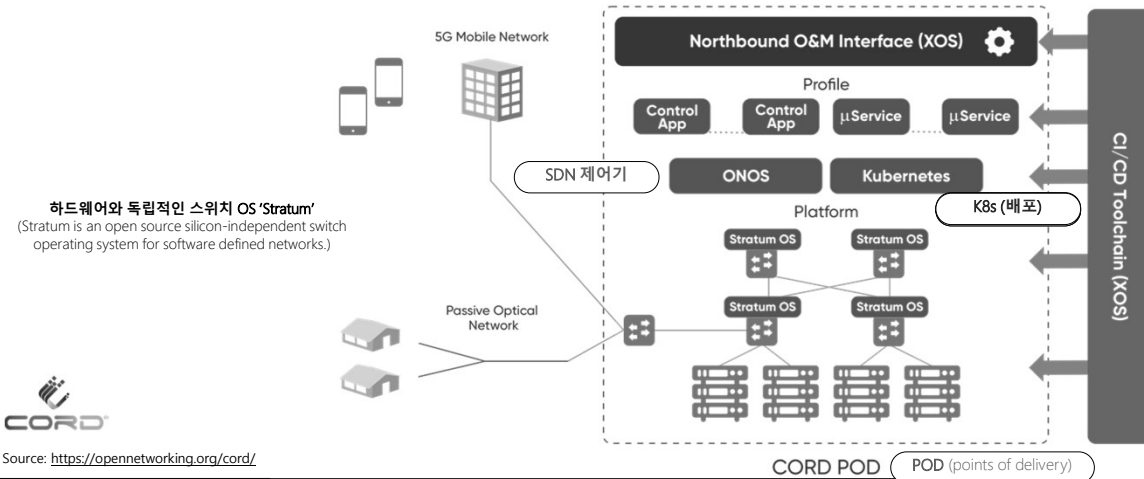
JS Lab

306

V. '관리/보안'

307

❖ CORD (Central Office Re-architected as a Datacenter)



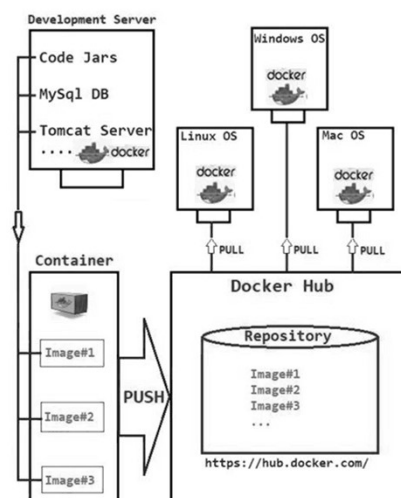
307

V. '관리/보안'

308

❖ Docker Image Creation Flow

- Docker Image Creation Flow

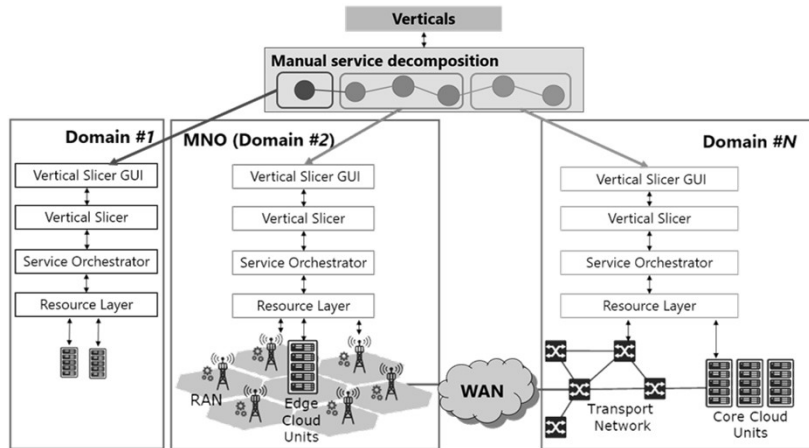


Source: https://javatechonline.com/how-to-deploy-spring-boot-application-in-docker/?fbclid=IwAR3ee4oHG1zTMkpi0khXj_r-nPIWfvDvl8tUcsGawNlJeXMXtLRdb5hvstK

308

V. '관리/보안'

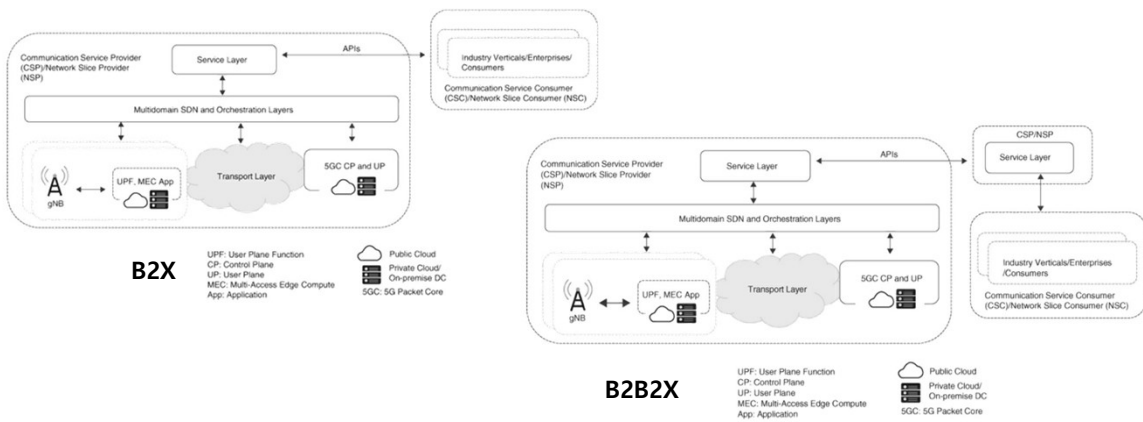
❖ Manual Vertical Service Decomposition



Source: 5GPPP Architecture Working Group, 5G Architecture White Paper

V. '관리/보안'

- ❖ NSaaS Deployment Method for B2X Offering
- ❖ NSaaS Deployment Method for B2B2X Offering

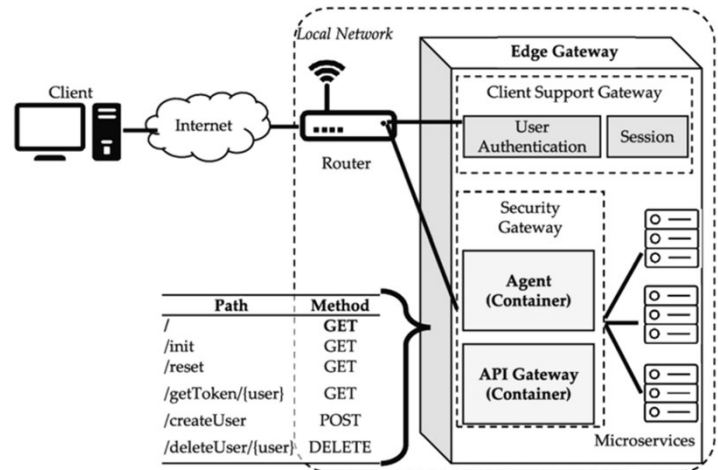


Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

V. '관리/보안'

311

- ❖ edge computing network architecture based on secure microservices.



Source: https://www.researchgate.net/figure/Proposed-edge-computing-network-architecture-based-on-secure-microservices_fig3_347267910

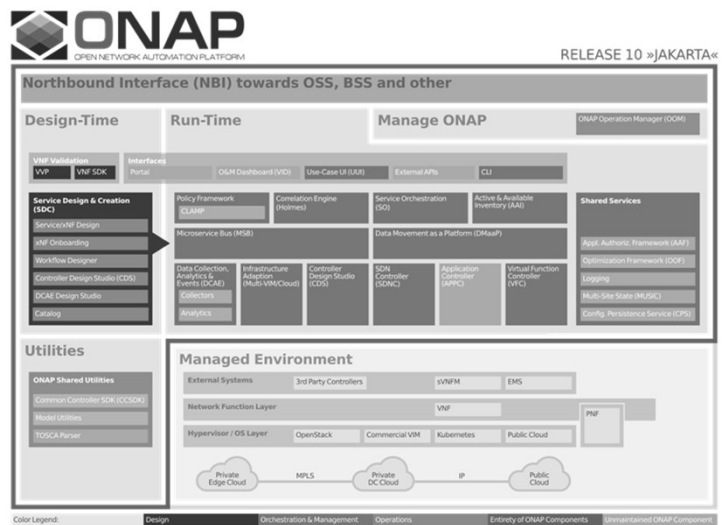
JS Lab

311

V. '관리/보안'

312

- ❖ ONAP architecture
 - high-level view of the ONAP architecture with its microservices-based platform components.



Source: <https://docs.onap.org/en/jakarta/guides/onap-developer/architecture/onap-architecture.html#architecture-overview>

JS Lab

312

V. '관리/보안'

313

❖ 리눅스재단(LF): LFN 5G Super Blueprints

CONFIGURATION & SECURITY MANAGEMENT

- Enable uniform and platform-level Service-Mesh Pattern Security
- Leverage open source projects including Istio, Envoy, K8S Ingress and Egress, Keycloak
- Allow security extensibilities with configurations/policies
- Support integration/deployment flexibilities with external IdAM and IdP

ONBOARDING & DESIGN

- Support VNF/CNF/PNF onboarding
- Conform to industry standard modeling and packaging

CONTAINERIZATION

- Container-based ONAP components support private, public and hybrid cloud infrastructures
- Manage complete lifecycle of ONAP components with OOM leveraging K8 ecosystem

ORCHESTRATION

- Support hybrid services CNF/VNF/PNF
- Provide ETSI-aligned and Cloud Native Orchestration
- Manage 3GPP compliant 5G slicing use cases

LFN 5G SUPER BLUEPRINTS

CROSS-COMMUNITY & SDO COLLABORATION

OBSERVABILITY & ANALYSIS

App - Log Generation → fluentbit → fluentd → elastic → Kibana

Support open Source & Standard-based Logging Architecture

- Decouple log generation from collection / aggregation / analysis processes
- Enable pick-and-choose solutions for monitoring, aggregating, storing and visualization
- Provide logging reference implementation

Source: <https://www.onap.org/software>

보안 관리

컨테이너화

커뮤니티 협력

온보딩/설계

오케스트레이션

가시화/분석



JS Lab

313

V. '관리/보안'

314

❖ Mavenir Converged Packet Core Solution Components

Network Slice Management and Orchestration

Mavenir Centralized Management System (mCMS) and Analytics (NWDAF)

Converged Packet Core				Subscriber and Data Management	Policy and Charging
2G/3G and 4G EPC SGSN, MME, SAEGW+GGSN, Media Engine, CGNAT	3G/4G/5G Combo NFs SMF+SAEGW-C, UPF+SAEGW-U (inc. GGSN-C/U)	5G Core Specific NFs AMF, NRF, NSSF, AUSF, SCP, BSF	Non-3GPP ePDG, TWAG, N3IWF, TNGF	UDM, UDR, HSS, UDSF	CCS/CHF, PCF+PCRF, eCGF
Security SeGW, EIR, SEPP					
IoT and SMS SCEF, NEF, SMSF					
2G to 5G – All G's Covered for All Deployment Types!					

Mavenir Webscale Platform (MWP) for Container Deployment
Mavenir Telco Cloud Integration Layer (MTCIL)

Mavenir PaaS (Platform as a Service)	Multi Cloud Deployment (Private and Public Cloud)
Mavenir CaaS (Container as a Service)	

Source: https://www.mavenir.com/wp-content/uploads/2022/02/CPC_Solution-Brief_020222_final.pdf



JS Lab

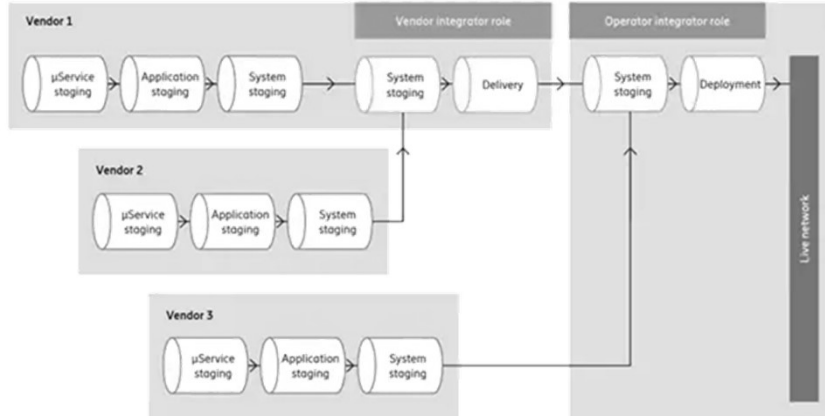
314

V. '관리/보안'

315

❖ 제조사 CI/CD (예): OSS/BSS in the Clouds

- Telecom phasing of software pipelines (CI/CD) and merging multiple vendors



Source: <https://www.ericsson.com/en/blog/2020/10/guide-to-building-cloudnative-infrastructure>



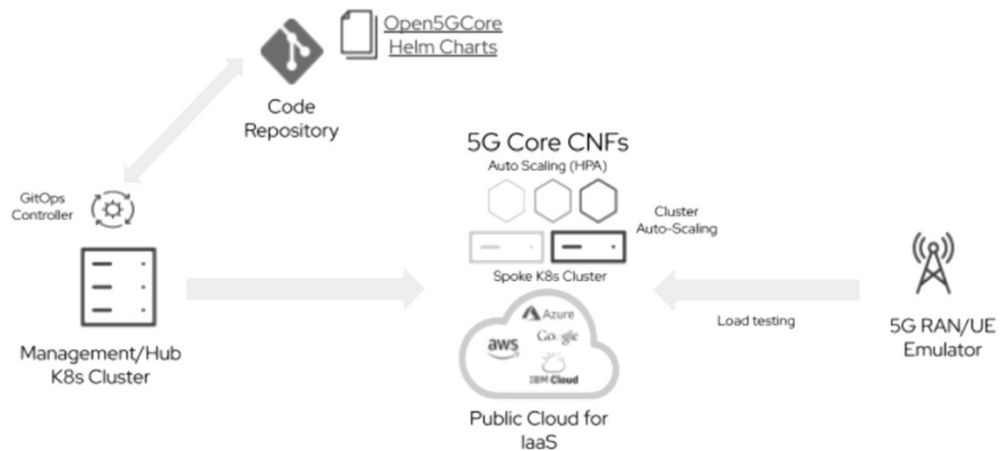
JS Lab

315

V. '관리/보안'

316

❖ 제조사 (예): Red Hat - Scaling a 5G platform



Source: Anca Pavel, Fatih E. Nar, Federico Rossi, and Mathias Bogebrant, CC BY-SA 4.0
Source: <https://www.redhat.com/architect/autoscale-5g-core>



JS Lab

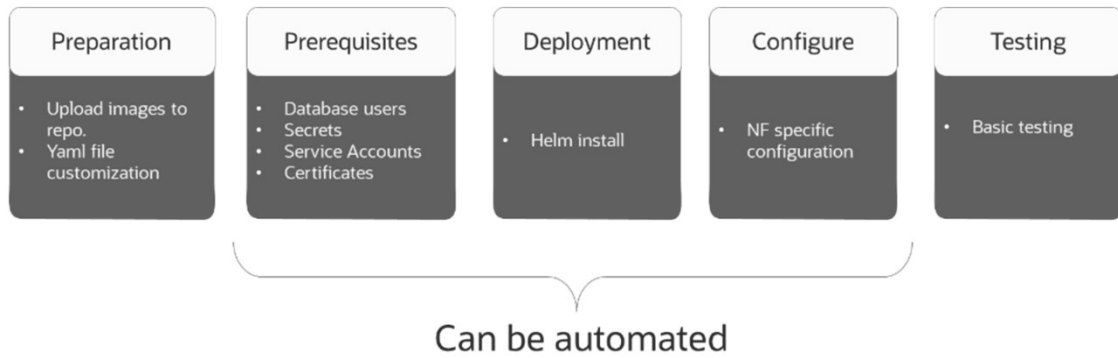
316

V. '관리/보안'

317

❖ NF deployment on the cloud infrastructure

• NF life cycle management



Source: <https://infohub.delltechnologies.com//dell-technologies-5g-core-validated-design-with-oracle-and-vmware-reference-architecture-guide-1/nf-deployment-on-the-cloud-infrastructure-1>



JS Lab

317

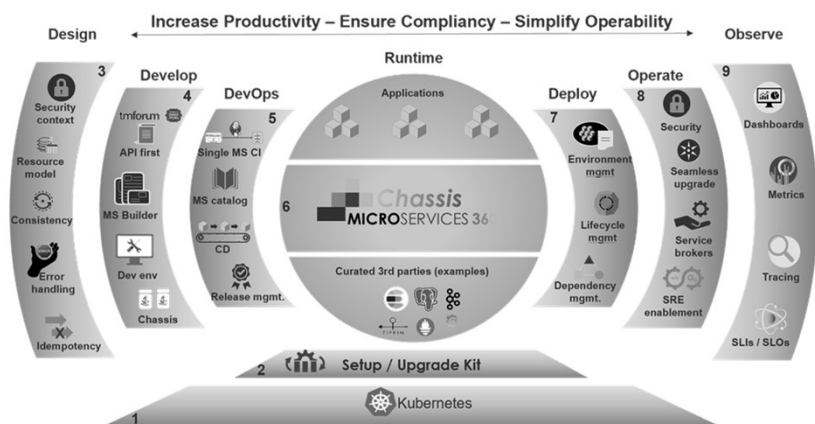
V. '관리/보안'

318

❖ 제조사 OSS/BSS Modernization (예): Red Hat and Intel

• Amdocs MS360 Cloud Native Development Platform

1. Kubernetes
2. Setup / Upgrade
3. Design
4. Develop
5. DevOps
6. Runtime
7. Deploy
8. Operate
9. Observe



Source: <https://telecoms.com/intelligence/oss-bss-modernization-amdocs-m360-cloud-native-development-platform/>



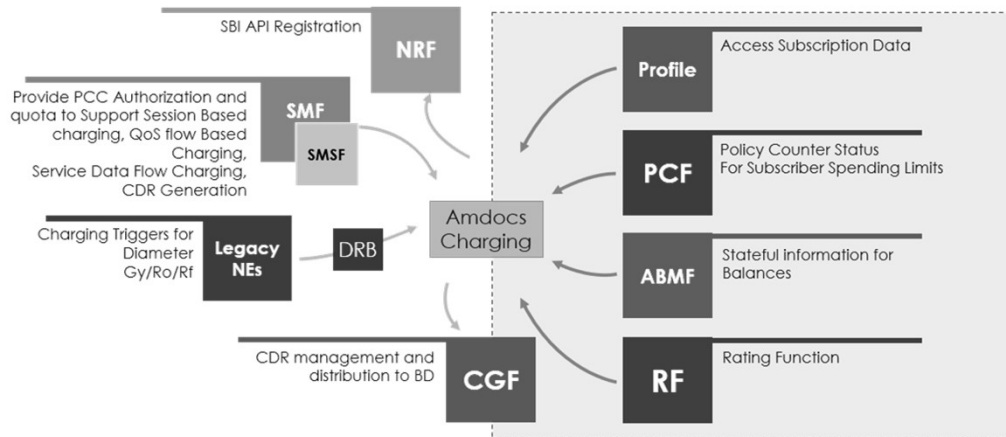
JS Lab

318

V. '관리/보안'

319

❖ Overview of Amdoc's converged charging system



Source: Source: Omdia OSS/BSS Evolution Survey – 2022
 Source: <https://www.oracle.com/a/ocom/docs/corporate/analystrelations/technology-analysis-converged-charging-in-5g.pdf>

JS Lab

319

V. '관리/보안'

320

❖ Open standards tools used for the development of each microservice

- **UAA** (User Account and Authentication)
- **API Gateway**
- **Cache**
- **Continuous Delivery**
- **Containers**
- **Cloud Platform**

UAA	okta	Apache DS	gluu	AWS IAM
API Gateway	WSO2	TreeGateway	AWS API Gateway	
Cache	redis	HEPSE	AWS Elastic Cache	
Continuous Delivery	git	Gradle	Jenkins	AWS Elastic Beanstalk
Containers	docker	kubernetes	MESOS	
Cloud Platform	openstack	IBM Bluemix	Microsoft Azure	amazon web services

Source: <https://beession.com/development-process/>

JS Lab

320

V. '관리/보안'

321

❖ Frameworks for web services for MSA

- Spring Boot
- Eclipse Vert.X
- Oracle Helidon
- GoMicro
- Molecular

Source: <https://www.mantisnet.com/blog/ebpf-v-sidecar-containers-5g-observability>



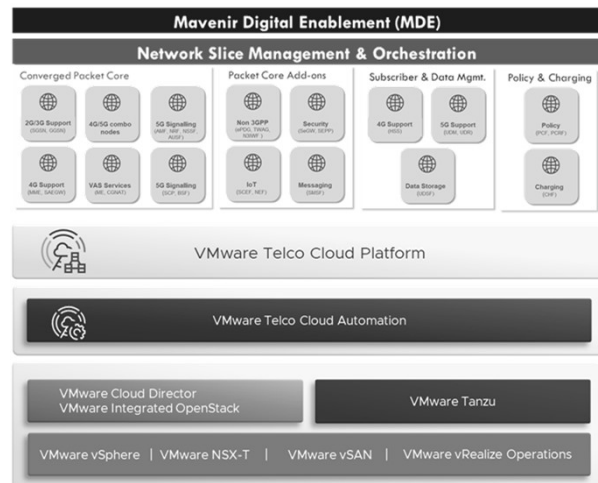
JS Lab

321

V. '관리/보안'

322

❖ Mavenir's Converged Packet Core on VMware Telco Cloud Platform. (VMware)



Source: <https://blogs.vmware.com/telco/mavenir-mwc-amer/>



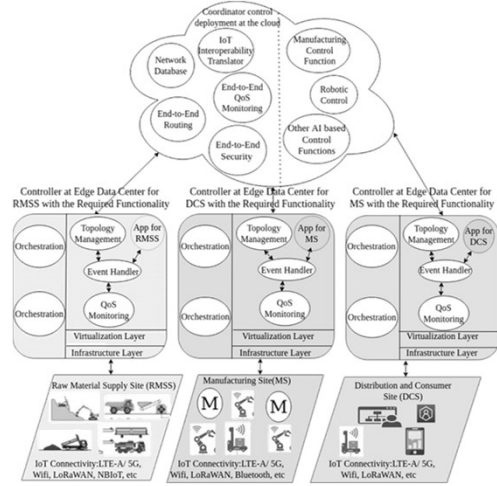
JS Lab

322

V. '관리/보안'

323

❖ Microservices-based SDN deployment blueprint in IIoT Scenarios



산업용 사물 인터넷(Industrial Internet of Things)
Source: https://www.researchgate.net/figure/Microservices-based-SDN-deployment-blueprint-in-IIoT-Scenarios_fig4_355473965

JS Lab

323

V. '관리/보안'

324

❖ IaC (예): Terraform

• AWS 랜딩존

Name	서브...	IPv4 CIDR
<input checked="" type="checkbox"/> 101subnet-1	subnet...	10.0.0.0/23
<input type="checkbox"/> 101subnet-2	subnet...	10.0.2.0/23
<input type="checkbox"/> 101subnet-private-1	subnet...	10.0.4.0/23
<input type="checkbox"/> 101subnet-private-2	subnet...	10.0.6.0/23
<input type="checkbox"/> 101subnet-pri-db1	subnet...	10.0.8.0/23
<input type="checkbox"/> 101subnet-pri-db2	subnet...	10.0.10.0/23

subnet-068809cf055800f49 / 101subnet-1

이제 Reachability Analyzer를 사용하여 네트워크 연결을 확인할 수 있습니다.

라우팅 테이블: rtb-031409dbf2ac9047 / main-default

라우팅 (2)

대상	대상
10.0.0.0/20	local
0.0.0.0/0	igw-0f9e147f66f1f7d0e

Source: <https://brunch.co.kr/@topasvqa/279/>

subnet-05616a12a08f8914 / 101subnet-private-1

이제 Reachability Analyzer를 사용하여 네트워크 연결을 확인할 수 있습니다.

라우팅 테이블: rtb-05bb48d9256663277 / main-private-1

라우팅 (2)

라우팅 테이블 (1)

라우팅 테이블 (1/3) - 2 섹션

Name	라우팅 테이블 ID	할당된 서브넷 범용
main-default	rtb-0465a32a8a27f94	-
main-private-1	rtb-05bb48d9256663277	subnet-05616a12a08f8914
main-private-2	rtb-05a129033a047676	subnet-06b0c0d024f8e...
main-private-db1	rtb-0865a94b7d7544f	subnet-06ca3809500566...
main-private-db2	rtb-086258f4a605f5718	subnet-091318f8aa1505...

```

terraform {
  required_providers {
    aws = {
      source = "hashicorp/aws"
      version = "~> 5.0"
    }
  }
}

provider "aws" {
  region = "ap-northeast-2"
}

resource "aws_vpc" "vpc" {
  cidr_block = "10.0.0.0/16"
  enable_dns_hostnames = true
}

resource "aws_subnet" "101subnet-1" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.0.0/23"
  availability_zone = "ap-northeast-2-a"
}

resource "aws_subnet" "101subnet-2" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.2.0/23"
  availability_zone = "ap-northeast-2-b"
}

resource "aws_subnet" "101subnet-private-1" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.4.0/23"
  availability_zone = "ap-northeast-2-a"
}

resource "aws_subnet" "101subnet-private-2" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.6.0/23"
  availability_zone = "ap-northeast-2-b"
}

resource "aws_subnet" "101subnet-pri-db1" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.8.0/23"
  availability_zone = "ap-northeast-2-a"
}

resource "aws_subnet" "101subnet-pri-db2" {
  vpc_id = aws_vpc.vpc.id
  cidr_block = "10.0.10.0/23"
  availability_zone = "ap-northeast-2-b"
}

resource "aws_route_table" "main-default" {
  vpc_id = aws_vpc.vpc.id
  route {
    cidr_block = "10.0.0.0/20"
    destination_prefix_list_id = aws_prefix_list.prefix-list-1.id
  }
  route {
    cidr_block = "0.0.0.0/0"
    gateway_id = aws_internet_gateway.internet-gateway-1.id
  }
}

resource "aws_route_table" "main-private-1" {
  vpc_id = aws_vpc.vpc.id
  route {
    cidr_block = "10.0.0.0/20"
    destination_prefix_list_id = aws_prefix_list.prefix-list-1.id
  }
}

resource "aws_route_table" "main-private-2" {
  vpc_id = aws_vpc.vpc.id
  route {
    cidr_block = "10.0.0.0/20"
    destination_prefix_list_id = aws_prefix_list.prefix-list-1.id
  }
}

resource "aws_route_table" "main-private-db1" {
  vpc_id = aws_vpc.vpc.id
  route {
    cidr_block = "10.0.0.0/20"
    destination_prefix_list_id = aws_prefix_list.prefix-list-1.id
  }
}

resource "aws_route_table" "main-private-db2" {
  vpc_id = aws_vpc.vpc.id
  route {
    cidr_block = "10.0.0.0/20"
    destination_prefix_list_id = aws_prefix_list.prefix-list-1.id
  }
}

resource "aws_internet_gateway" "internet-gateway-1" {
  vpc_id = aws_vpc.vpc.id
}

resource "aws_prefix_list" "prefix-list-1" {
  vpc_id = aws_vpc.vpc.id
  address_family = "IPv4"
  prefix_list_scope = "regional"
  prefix_list_name = "prefix-list-1"
  prefix_list_cidr_blocks = ["10.0.0.0/20"]
}

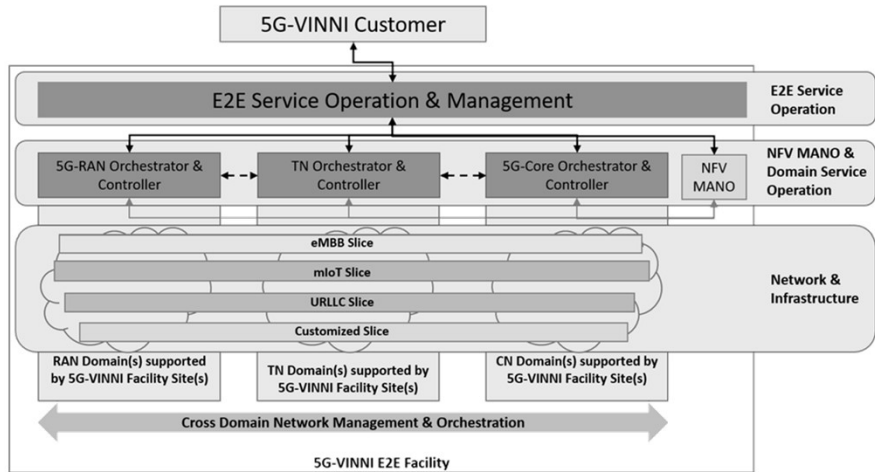
```

JS Lab

324

V. '관리/보안'

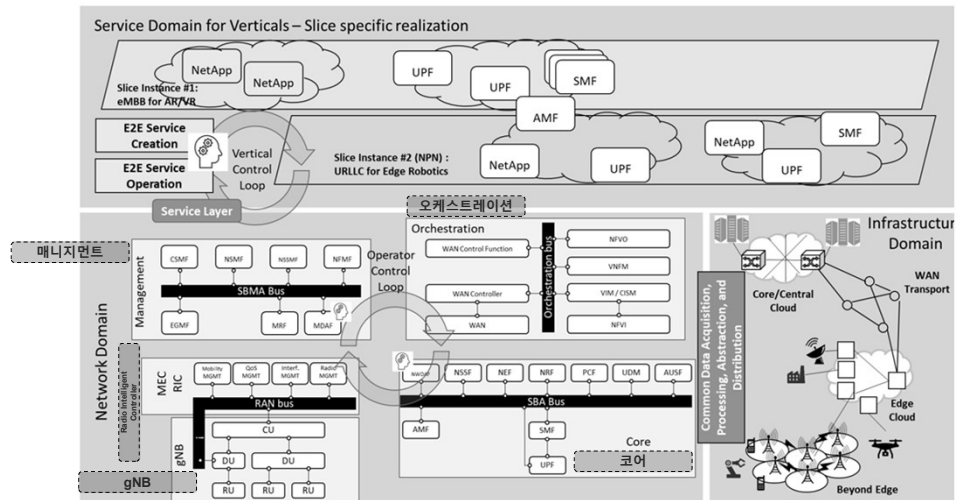
❖ elastic MEC-enabled E2E slices



Source: 5GPPP Architecture Working Group 5G Architecture - White Paper

V. '관리/보안'

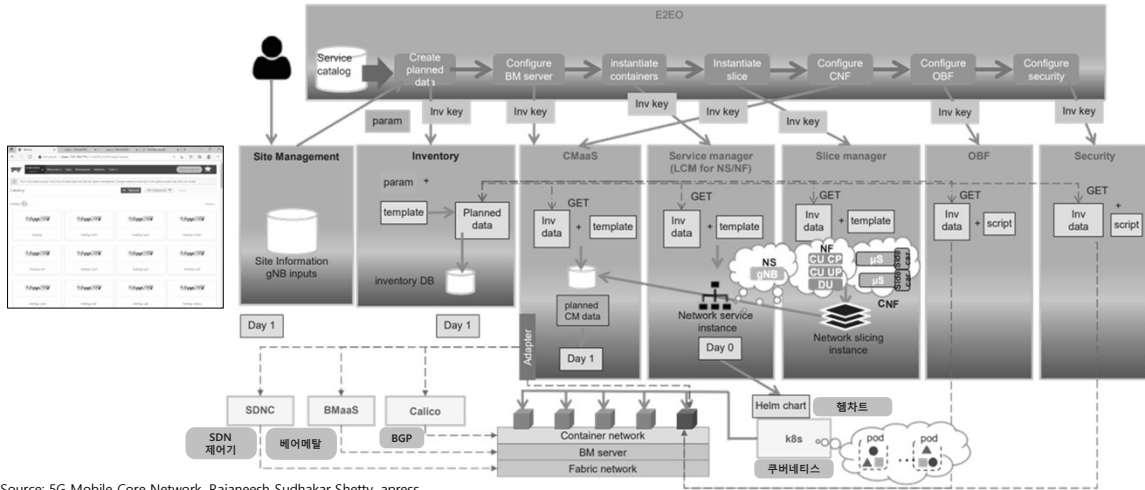
❖ 5GPPP: Overall 5G architecture



V. '관리/보안'

327

❖ 종단간 오케스트레이션: End-to-end orchestration functionalities



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apress

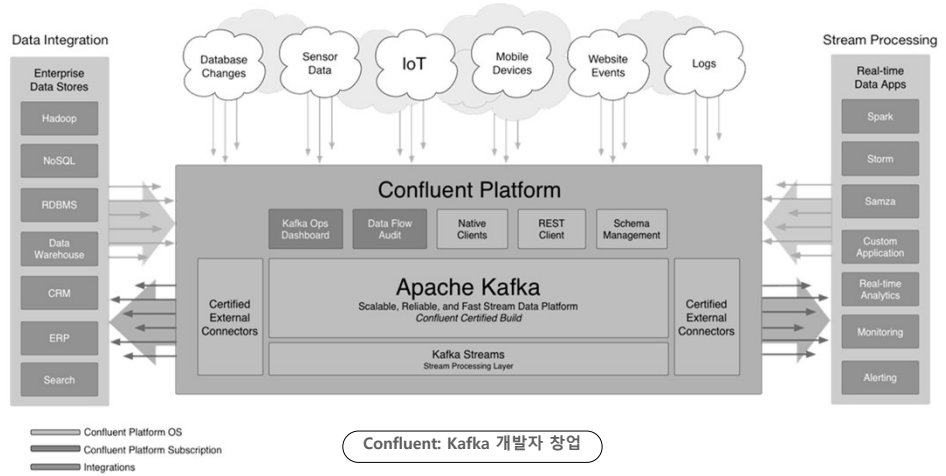
JS Lab

327

V. '관리/보안'

328

❖ Stream Processing (예: Confluent Platform)



Source: <https://docs.confluent.io/2.0.0/platform.html>

JS Lab

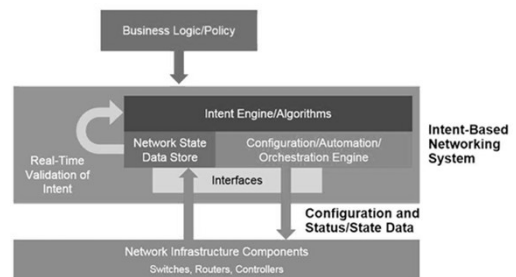
328

V. '관리/보안'

329

❖ 인텐트 기반 네트워킹(IBN)

- 네트워크 사용자의 의도(Intent)에 맞는 네트워크 서비스를 효율적으로 제공하고자 하는 개념
- AI 기술과 결합 되면서 네트워크 제어 및 관리 분야에서 자동화 네트워크를 구현
- 기능 요소: 인텐트를 해석, 네트워크 자원 배정을 배정, 폐쇄 제어 루프
- IETF에서는 통신 분야의 IBN과 관련된 용어/개념/기본 구조를 제시하는 RFC 9315 표준 제시
- 오픈소스 (예): Linux Foundation의 ONAP 플랫폼



Source: 네트워크 자동화 오픈 플랫폼 동향: IETF IBN & LF ONAP, NIA, 경남대학교 석승준교수

© 2017 Gartner, Inc



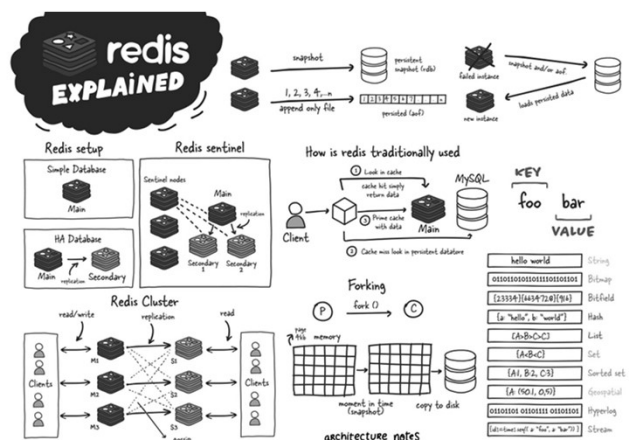
JS Lab

329

V. '관리/보안'

330

- ❖ Open and Standards-based
- ❖ The Pathway to Software Control and Automation



Source: <https://www.ecosmob.com/key-microservices-trends-for-2022/>

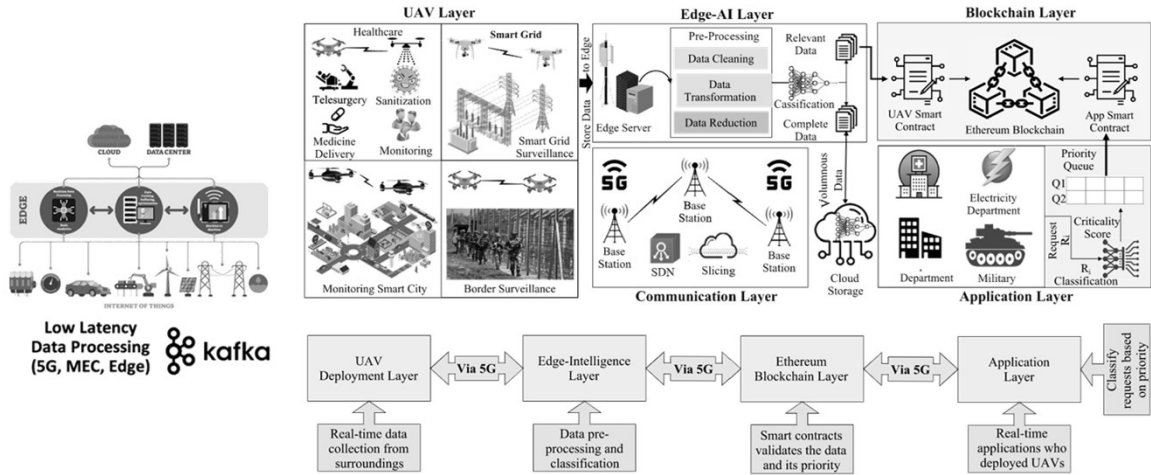


JS Lab

330

V. '관리/보안'

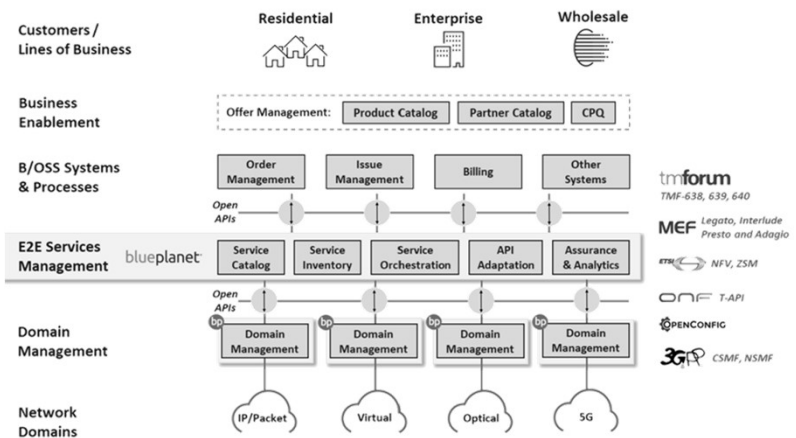
❖ Loosely coupled applications



Source: <https://onlinelibrary.wiley.com/doi/epdf/10.1002/ett.4176>

V. '관리/보안'

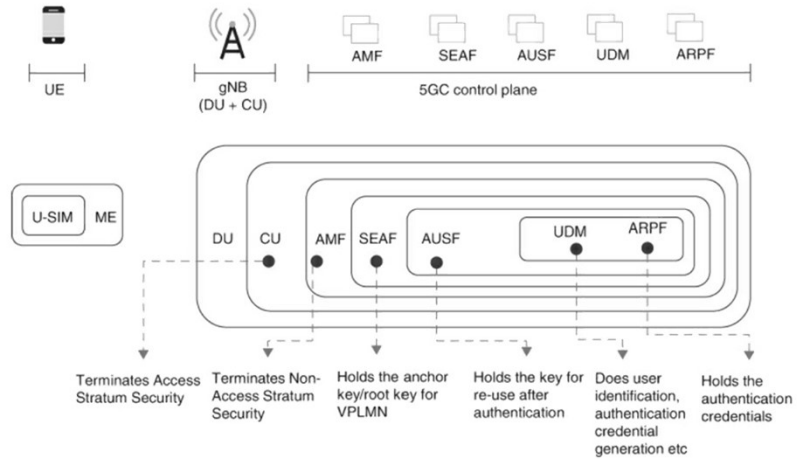
❖ Open and Standards-based - The Pathway to Software Control and Automation



Source: <https://www.ecosmob.com/key-microservices-trends-for-2022/>

V. '관리/보안'

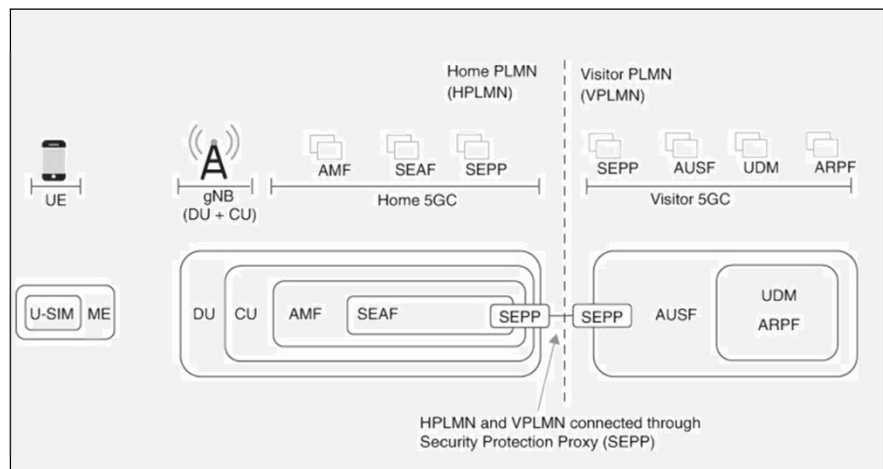
❖ Trust Model for 5G Non-Roaming Architecture



Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

V. '관리/보안'

❖ Trust Model for 5G Roaming Architecture

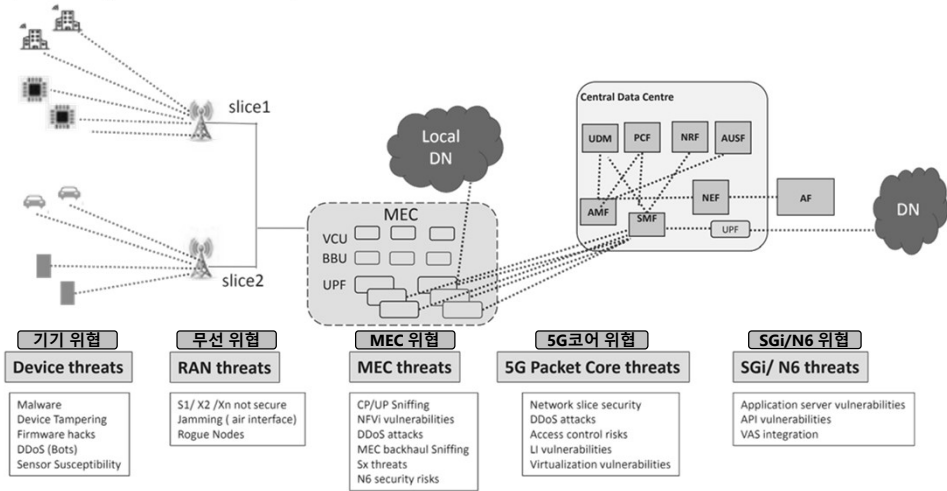


Source: Nair, Pramod (2021-12-06T22:58:59.000). Securing 5G and Evolving Architectures . Pearson Education. Kindle Edition.

V. '관리/보안'

335

❖ 5G 보안 위협 (Security threats in 5G)



Source: 5G Mobile Core Network, Rajaneesh Sudhakar Shetty, apres

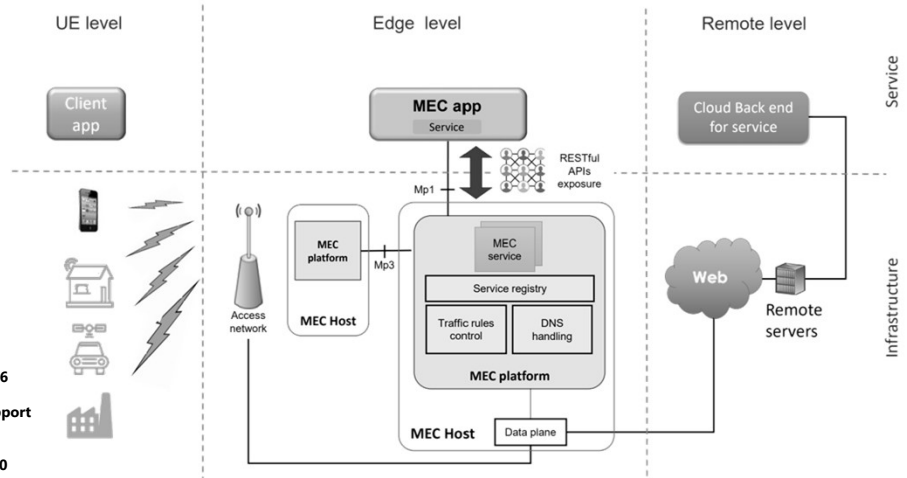
JS Lab

335

V. '관리/보안'

336

❖ ETSI의 MEC 보안: MEC applications, interaction and service exposure



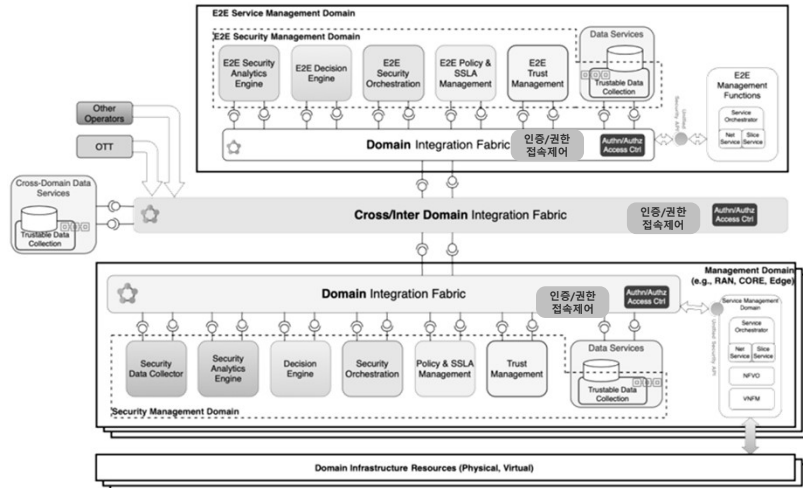
ETSI White Paper No. 46
MEC security:
Status of standards support
and future evolutions
1st edition – May 2021
ISBN No. 979109262040

JS Lab

336

V. '관리/보안'

❖ Security Framework High-Level Architecture

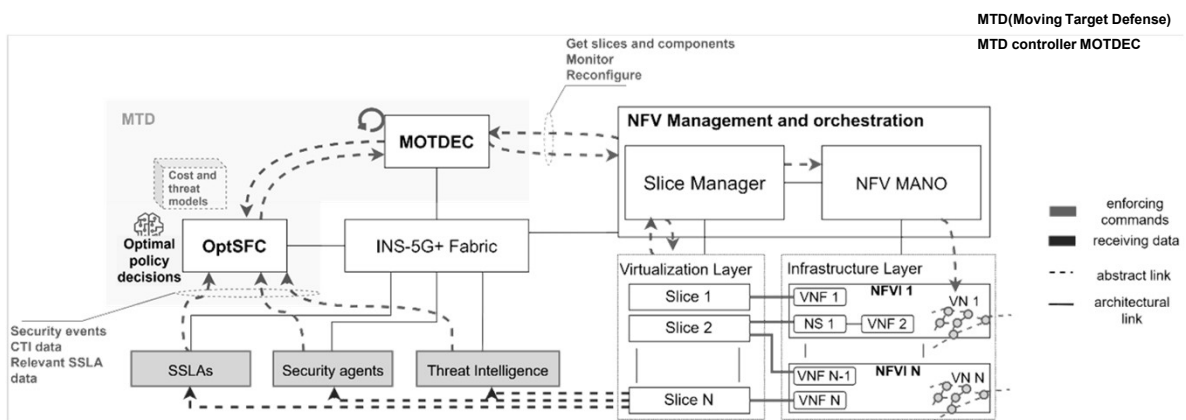


Source: 5GPPP Architecture Working Group 5G Architecture - White Paper

V. '관리/보안'

❖ Security (보안)

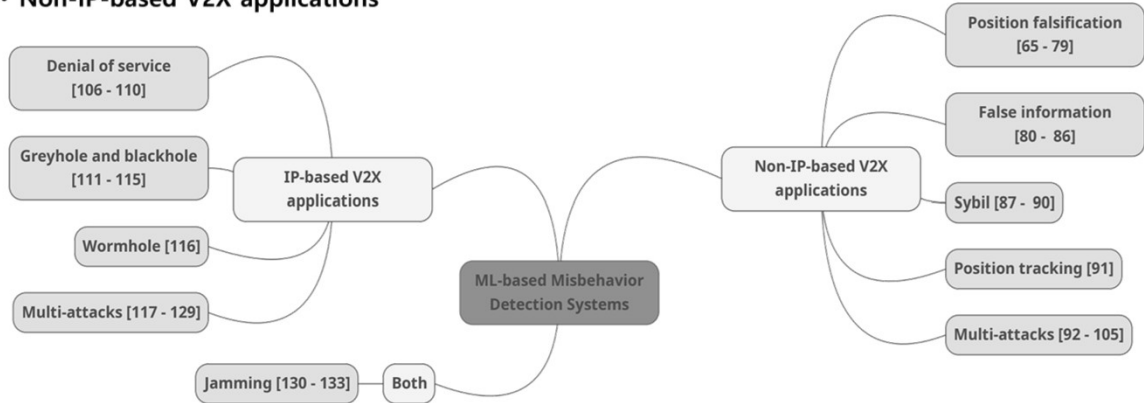
- MTD for network slice protection



Source: AI and ML – Enablers for Beyond 5G Networks' (URL <http://doi.org/10.5281/zenodo.4299895>) , 5G PPP Technology Board, 2021-05-11

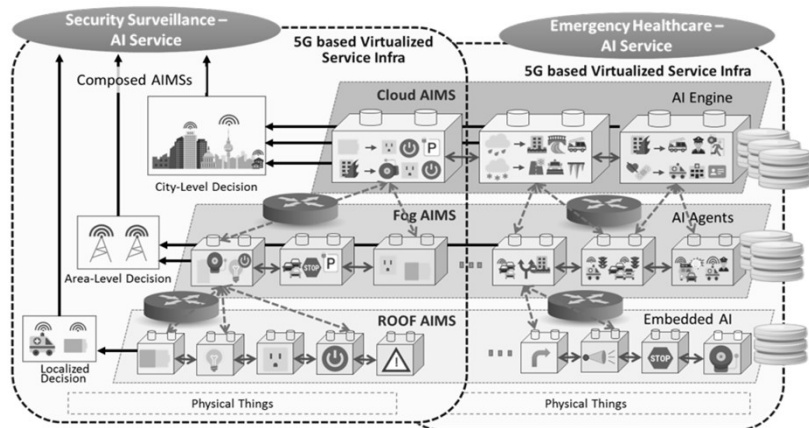
❖ Taxonomy of ML-based Misbehavior Detection Systems

- IP-based V2X applications
- Non-IP-based V2X applications



Source: A Survey on Machine Learning-based Misbehavior Detection Systems for 5G and Beyond Vehicular Network, Abdelwahab Boulouache, Member, IEEE and Thomas Engel, Member, IEEE

❖ AIMS Use Cases

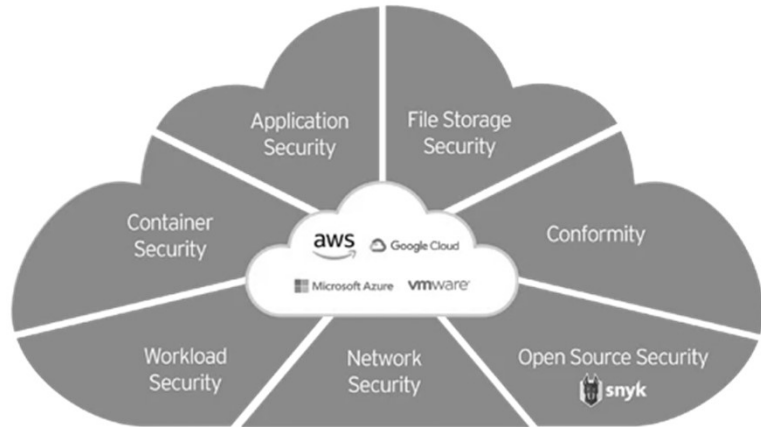


Source: https://www.itu.int/en/ITU-T/academia/kaleidoscope/2018/Documents/Presentations/S2.2_AI%20as%20a%20Microservice_UM.pdf

V. '관리/보안'

341

❖ 제조사 (예): Trend Micro - Cloud One Open Source Security



Source: https://www.trendmicro.com/en_nz/business/products/hybrid-cloud/cloud-one-open-source-security-by-snyk.html



JS Lab

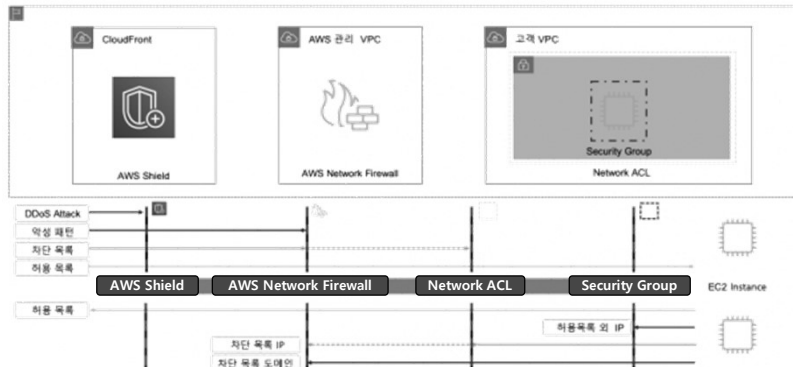
341

V. '관리/보안'

342

❖ AWS 가상네트워크(VPC) 인프라 보안: AWS 서비스 보안

- AWS 실드(AWS Shield)
- AWS 네트워크 방화벽(AWS Network Firewall)
- NACL(Network Access Control List)
- 보안 그룹(Security Group)
- 데이터 암호화



Source: <http://www.datanet.co.kr/news/articleView.html?idxno=178057>



JS Lab

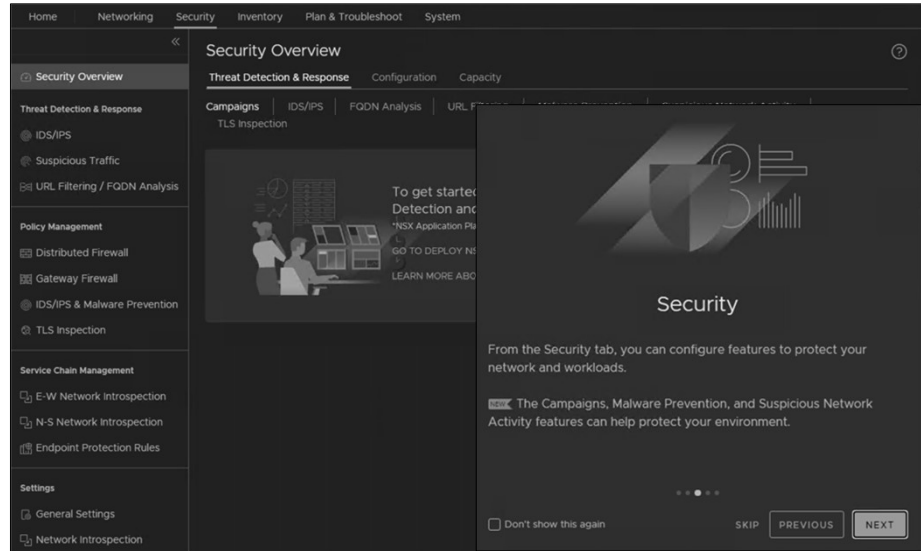
342

V. '관리/보안'

343

❖ NSX Dashboard

- Home
- Networking
- Security
- Inventory
- Plan & Troubleshoot
- System



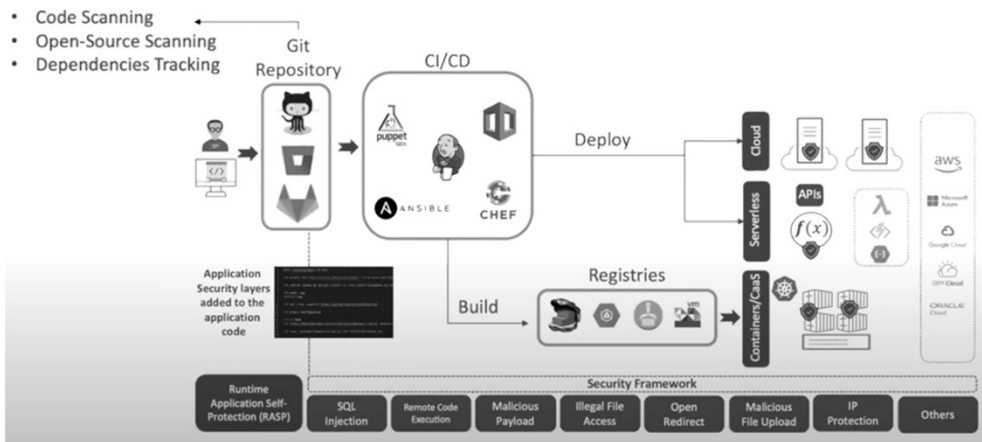
JS Lab

343

V. '관리/보안'

344

❖ 제조사 (예): Trend Micro - Embedding Microservices Security



Source: https://www.trendmicro.com/en_dk/devops/22/a/microservice-security-how-to-proactively-protect-apps.html

JS Lab

344

V. '관리/보안'

345

❖ 클라우드 디자인 패턴

- 디자인 패턴은 클라우드에서 안정적이고 확장성 있는 안전한 애플리케이션을 빌드하는데 유용
- 각 패턴은 패턴이 해결하는 문제, 패턴을 적용하기 위한 고려
- 클라우드 플랫폼에 호스팅, 분산 시스템과 관련
 - 가용성
 - 데이터 관리
 - 디자인 및 구현
 - 메시징
 - 관리 및 모니터링
 - 성능 및 확장성
 - 복원력
 - 보안



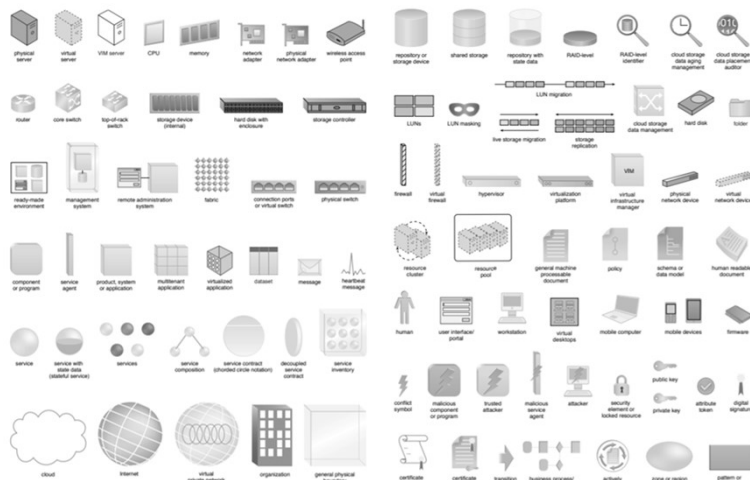
JS Lab

345

V. '관리/보안'

346

❖ 클라우드 디자인 패턴 구성 (2015)



Source: Erl, Thomas. Cloud Computing Design Patterns (The Prentice Hall Service Technology Series from Thomas Erl) . Pearson Education.



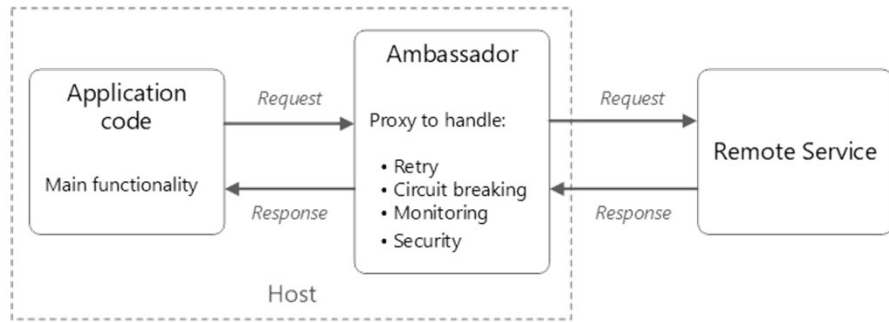
JS Lab

346

V. '관리/보안'

349

❖ 특사(Ambassador) 패턴



Source: <https://docs.microsoft.com/ko-kr/azure/architecture/patterns/>



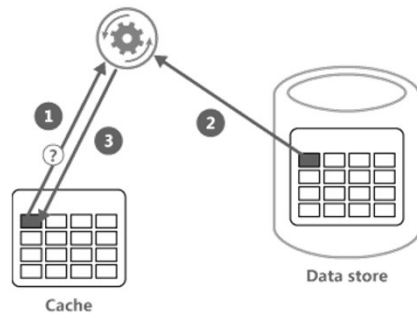
JS Lab

349

V. '관리/보안'

350

❖ Cache-Aside pattern



- 1: Determine whether the item is currently held in the cache.
- 2: If the item is not currently in the cache, read the item from the data store.
- 3: Store a copy of the item in the cache.

Source: <https://docs.microsoft.com/ko-kr/azure/architecture/patterns/>



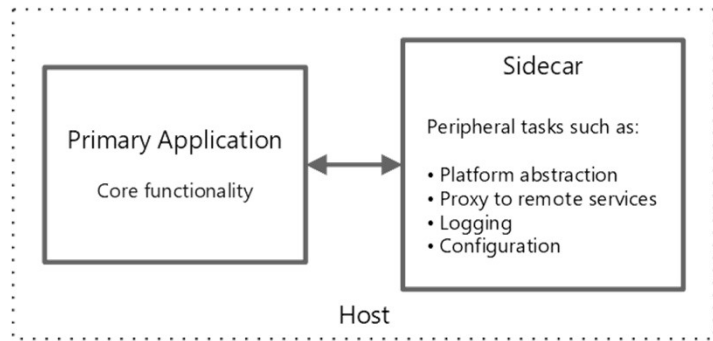
JS Lab

350

V. '관리/보안'

351

❖ 사이드카(Sidecar) 패턴



Source: <https://docs.microsoft.com/ko-kr/azure/architecture/patterns/>



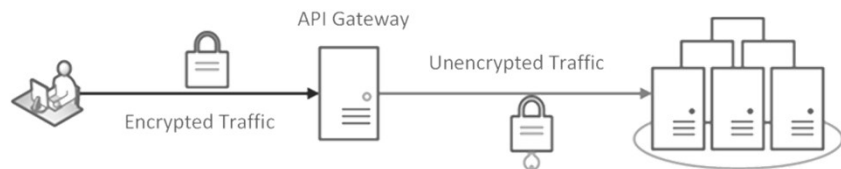
JS Lab

351

V. '관리/보안'

352

❖ 게이트웨이 오프로딩 패턴



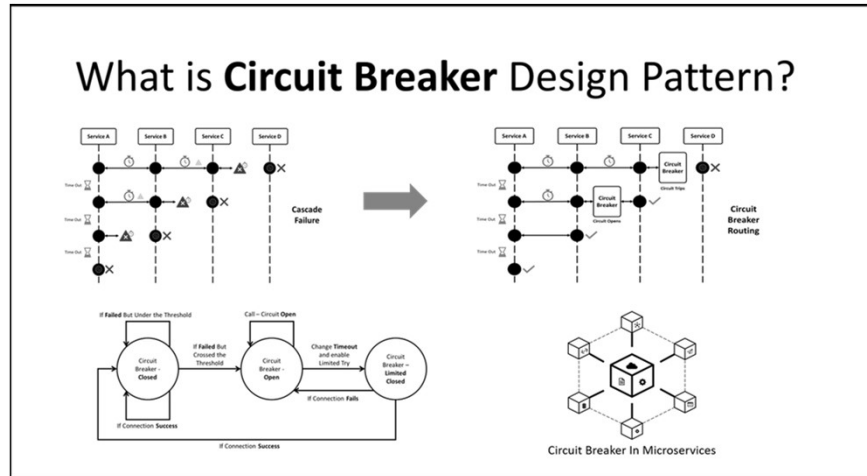
Source: <https://docs.microsoft.com/ko-kr/azure/architecture/patterns/>



JS Lab

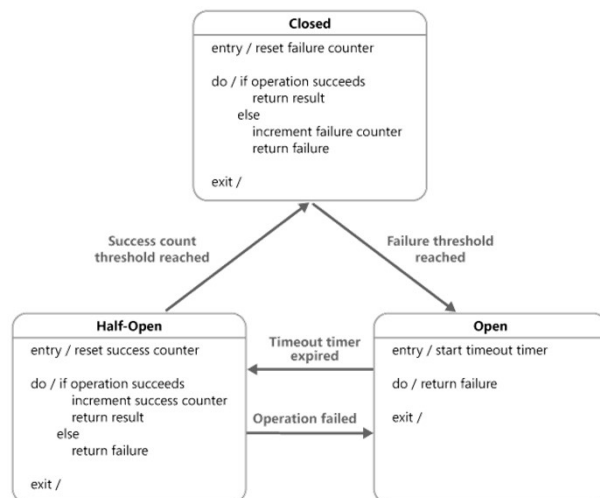
352

❖ What is Circuit Breaker Design Pattern?



Source: https://digitalvargs.com/what-is-circuit-breaker-design-pattern/?fbclid=IwAR1uukaeNh-vjZXeLhQP2MZvpeq7NVeNVKHmjNEPubzrh8vISlwr_Dedph8

❖ 회로 차단기 패턴



Source: <https://docs.microsoft.com/ko-kr/azure/architecture/patterns/>



부록1. OPENSTACK (1 OF 3)

356

❖ Loosely coupled architecture

- Default ports

서비스 배포는 API를 사용하는 컨테이너 또는 쿠버네티스의 POD로 구현 가능 구조

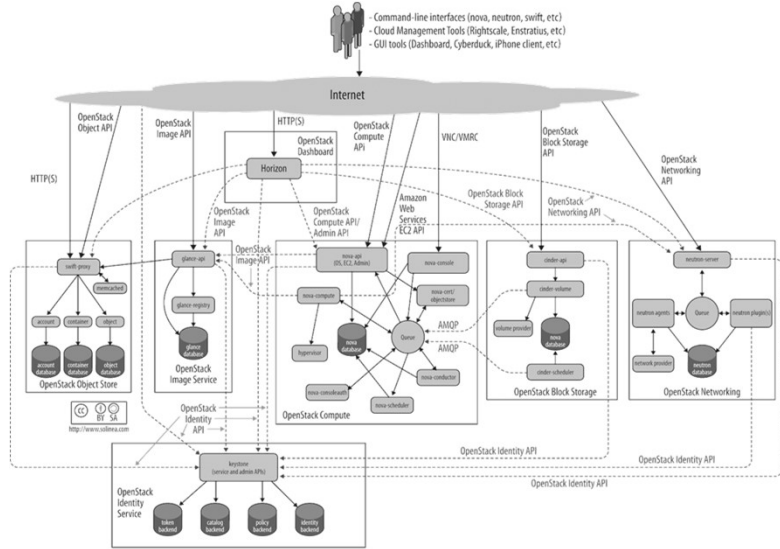
Default ports that secondary services related to OpenStack components use

Service	Default port	Used by
HTTP	80	OpenStack dashboard (Horizon) when it is not configured to use secure access.
HTTP alternate	8080	OpenStack Object Storage (swift) service.
HTTPS	443	Any OpenStack service that is enabled for SSL, especially secure-access dashboard.
rsync	873	OpenStack Object Storage. Required.
ISCSI target	3260	OpenStack Block Storage. Required.
MySQL database service	3306	Most OpenStack components.
Message Broker (AMQP traffic)	5672	OpenStack Block Storage, Networking, Orchestration, and Compute.

OpenStack components use	Default ports
Application Catalog (murano)	8082
Backup Service (Freezer)	9090
Big Data Processing Framework (sahara)	8386
Block Storage (cindervolume)	8776
Clustering (senlin)	8777
Compute (nova) endpoints	8774
Compute ports for access to virtual machine consoles	5900-5999
Compute VNC proxy for browsers (openstack-nova-novncproxy)	6080
Compute VNC proxy for traditional VNC clients (openstack-nova-xvncproxy)	6081
Container Infrastructure Management (Magnum)	9511
Container Service (Zun)	9517
Data processing service (sahara) endpoint	8386
Database service (Trove)	8779
DNS service (Designate)	9001
High Availability Service (Masakari)	15868
Identity service (keystone) endpoint	5000
Image service (glance) API	9292
Key Manager service (Barbican)	9311
Loadbalancer service (Octavia)	9876
Networking (neutron)	9696
NFV Orchestration service (tacker)	9890
Object Storage (swift)	6000, 6001, 6002
Orchestration (heat) endpoint	8004
Orchestration AWS CloudFormation-compatible API (openstack-heat-api-cfn)	8000
Orchestration AWS CloudWatch-compatible API (openstack-heat-api-cloudwatch)	8778
Placement API (placement)	8003
Proxy port for HTML5 console used by Compute service	6082
Rating service (Cloudkitty)	8889
Registration service (Adjutant)	5050
Resource Reservation service (Blazar)	1234
Root Cause Analysis service (Vitrage)	8999
Shared File Systems service (Manila)	8786
Telemetry alarming service (Aodh)	9042
Telemetry event service (Panko)	8977
Workflow service (Mistral)	8989

부록1. OPENSTACK (2 OF 3)

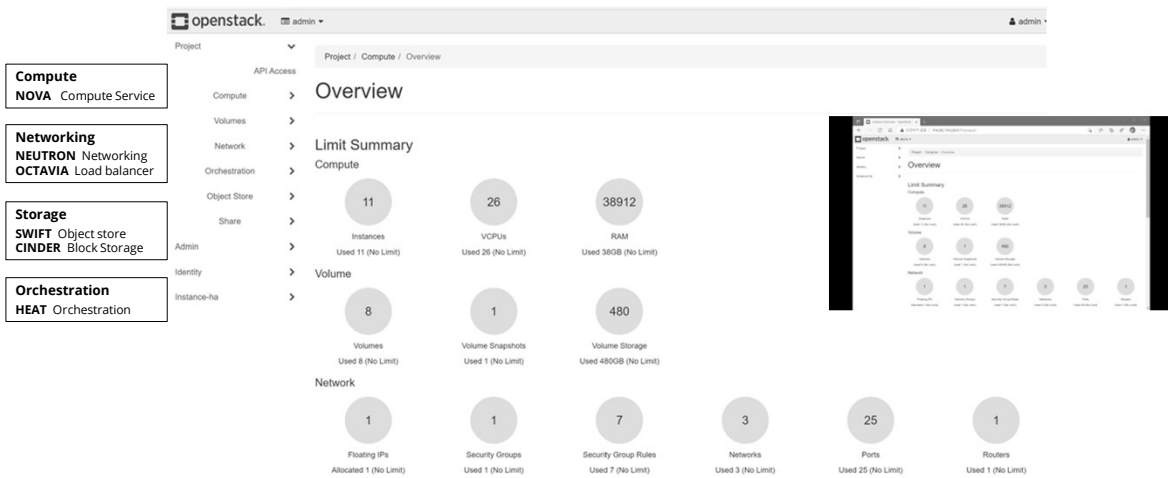
❖ OpenStack Design



Return: [I. 'MSA와 5G 네트워크'](#)

부록1. OPENSTACK (3 OF 3)

❖ OpenStack Horizon (Web Frontend)



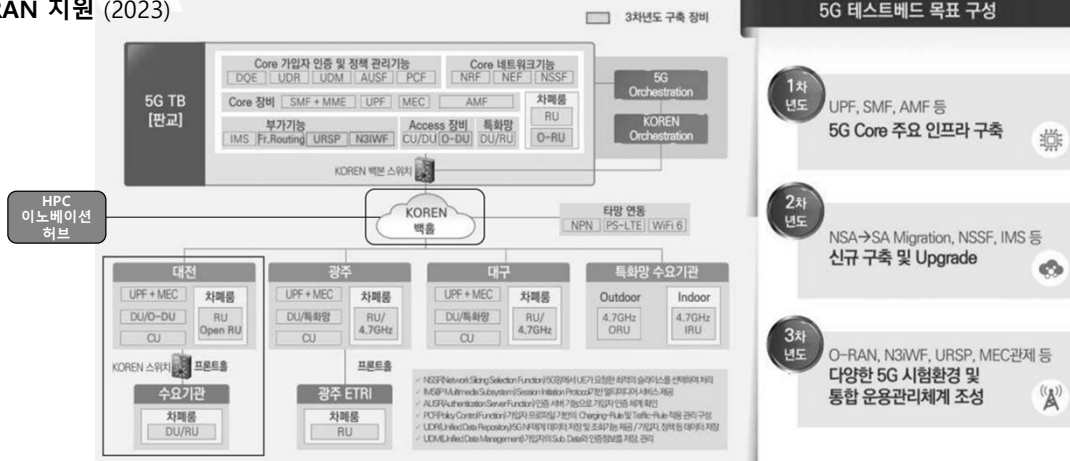
Return: [I. 'MSA와 5G 네트워크'](#), [II. '가상화 \(Virtualization\) 인프라'](#)

부록2. 5G 융합서비스 테스트베드 (1 OF 2)

359

❖ 5G 융합서비스 테스트베드 (@KOREN)

• O-RAN 지원 (2023)



Source: https://ettrends.etri.re.kr/ettrends/197/0905197007/060-069_%EC%98%88%EC%86%A9%EC%9D%BC_197%ED%98%B8.pdf

JS Lab

359

부록2. 5G 융합서비스 테스트베드 (2 OF 2)

360

❖ 5G 융합서비스 테스트베드 (@KOREN)

• 대전 거점 (ETRI)



Return: Slide 27

JS Lab

360

부록3. SPRING CLOUD (1 OF 2)

361

❖ Spring cloud vs Kubernetes

Microservices Concern	Spring Cloud & Netflix OSS	Kubernetes
Configuration Management	Config Server, Consul, Netflix Archaius	Kubernetes ConfigMap & Secrets
Service Discovery	Netflix Eureka, Hashicorp Consul	Kubernetes Service & Ingress Resources
Load Balancing	Netflix Ribbon	Kubernetes Service
API Gateway	Netflix Zuul	Kubernetes Service & Ingress Resources
Service Security	Spring Cloud Security	-
Centralized Logging	ELK Stack (LogStash)	EFK Stack (Fluentd)
Centralized Metrics	Netflix Spectator & Atlas	Heapster, Prometheus, Grafana
Distributed Tracing	Spring Cloud Sleuth, Zipkin	OpenTracing, Zipkin
Resilience & Fault Tolerance	Netflix Hystrix, Turbine & Ribbon	Kubernetes Health Check & resource isolation
Auto Scaling & Self Healing	-	Kubernetes Health Check, Self Healing, Autoscaling
Packaging, Deployment & Scheduling	Spring Boot	Docker/Rkt, Kubernetes Scheduler & Deployment
Job Management	Spring Batch	Kubernetes Jobs & Scheduled Jobs
Singleton Application	Spring Cloud Cluster	Kubernetes Pods

Share: <https://velog.io/@formin/Spring-Cloud%EB%A5%BC-%ED%99%9C%EC%9A%A9%ED%95%9C-MSA-%EC%84%A4%EC%B9%98-%EB%B0%8F-%EA%B5%AC%EC%84%B1>



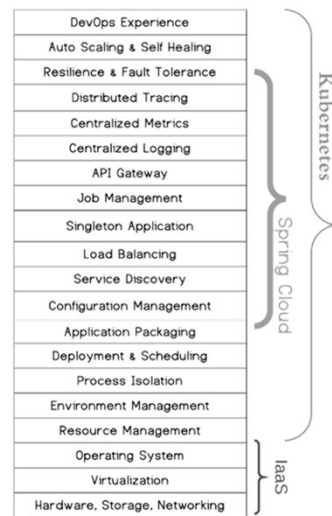
JS Lab

361

부록3. SPRING CLOUD (2 OF 2)

362

❖ Spring cloud vs Kubernetes



Return: [I. 'MSA와 5G 네트워크' 6p](#), [I. 'MSA와 5G 네트워크' 90p](#)
 Share: <https://www.steemcoinpan.com/hive-101145/@wonsama/msa>



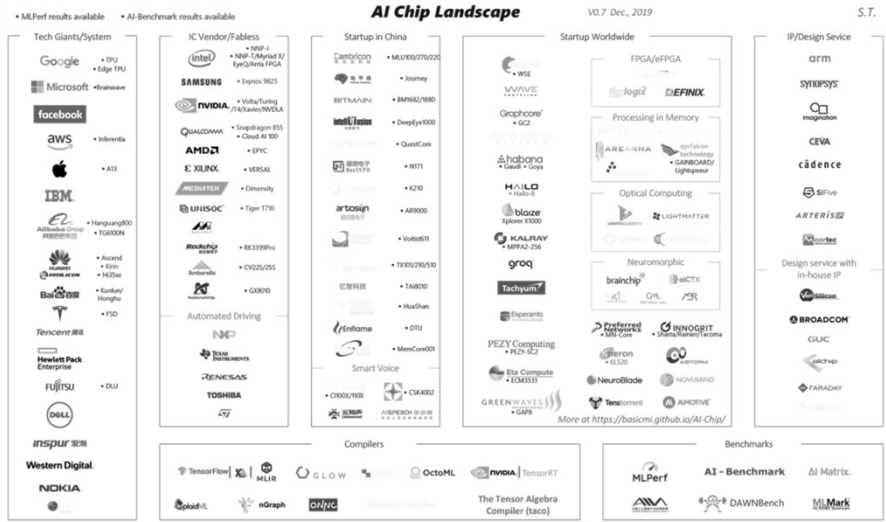
JS Lab

362

부록4. AI CHIP LANDSCAPE

❖ AI Chip Landscape

- Tech Giants/System
- IC Vendor/Fabless
- Startup
- IP/Design Service
- Compilers
- Benchmarks

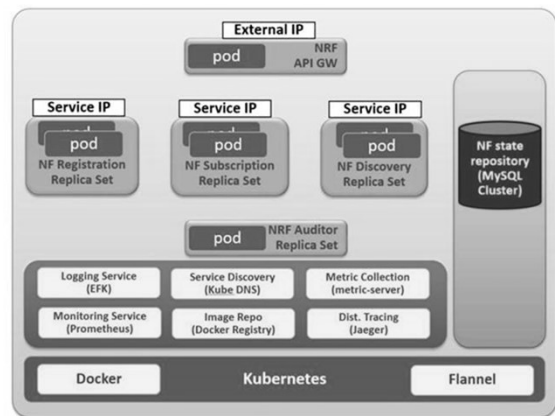
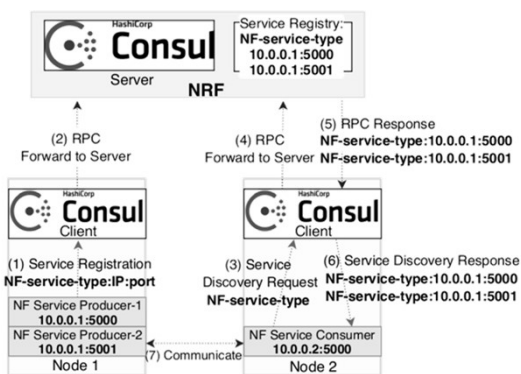


Return: [인 '가상화 \(Virtualization\) 인프라'](https://github.com/basicml/AI-Chip)
Source: <https://github.com/basicml/AI-Chip>

All information contained within this infographic is gathered from the internet and periodically updated, no guarantee is given that the information provided is correct, complete, and up-to-date.

부록5. 제조사 NRF (1 OF 2)

- ❖ 해시코프: NRF implementation using Consul
- ❖ 오라클: Communications Network Repository Function (NRF) Cloud Native

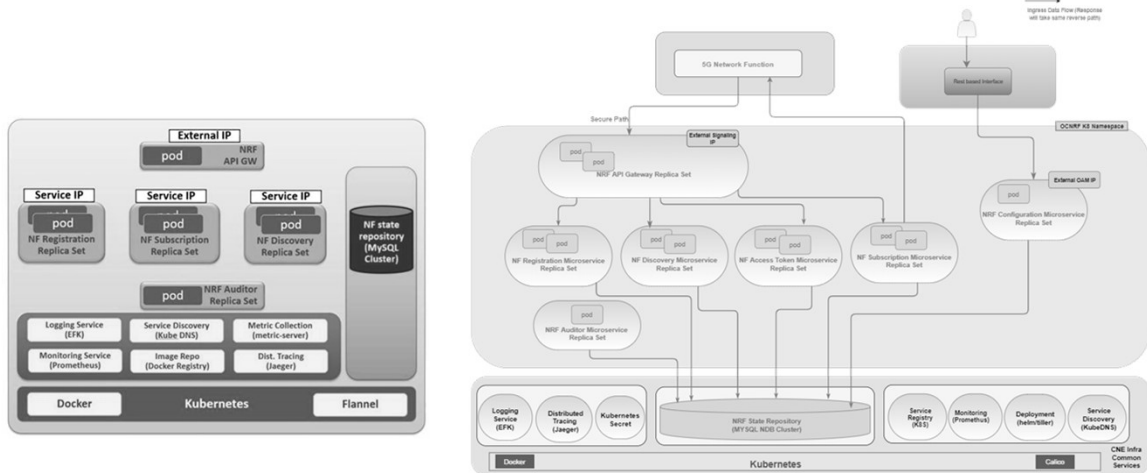


Source: <https://pdfs.semanticscholar.org/52f6/001a27f827d3c724a8718e6768cd35ceb178.pdf>
Source: https://docs.oracle.com/communications/F21353_01/docs.10/NRF%20User%27%20Guide/GUID-72930D10-8817-4F82-83C2-695FC485589B.htm

부록5. 제조사 NRF (2 OF 2)

365

❖ 오라클: Communications Network Repository Function (NRF) Cloud Native



Return: Slide 199 , Slide 228

Source: https://docs.oracle.com/communications/F25434_01/docs.10/NRF%20User%27s%20Guide/GUID-72930D10-8817-4F82-83C2-695FC4B5589B.htm



JS Lab

365

부록6. SYSTEM MONITORING SOFTWARE

366

❖ System Monitoring Software

- | | |
|---|--|
| 1.NinjaOne (Formerly NinjaRMM) | 1. Sematext Monitoring |
| 2.SolarWinds Server and Application Monitor | 2. SolarWinds Server & Application Monitor |
| 3.Atera | 3. Atera |
| 4.eG Innovations | 4. Datadog Infrastructure Monitoring |
| 5.Datadog | 5. Site24x7 Server Monitoring |
| 6.Site24x7 | 6. Paessler PRTG Network Monitor |
| 7.Sematext | 7. ManageEngine Applications Manager |
| 8.PRTG Network Monitor | 8. Nagios |
| 9.Zabbix | 9. Zabbix |
| 10.Spiceworks Network Monitor | 10. NinjaOne |
| 11.Nagios | 11. Spiceworks |
| 12.OpManager by ManageEngine | |
| 13.WhatsUp Gold | |
| 14.Cacti | |
| 15.Icinga | |
| 16.OpenNMS | |

Return: Slide 240

Source: <https://www.softwaretestinghelp.com/system-monitoring-software/> , <https://sematext.com/blog/system-monitoring-tools/>



JS Lab

366