AIOps: 透過機器學習打造新世代的5G營運平台
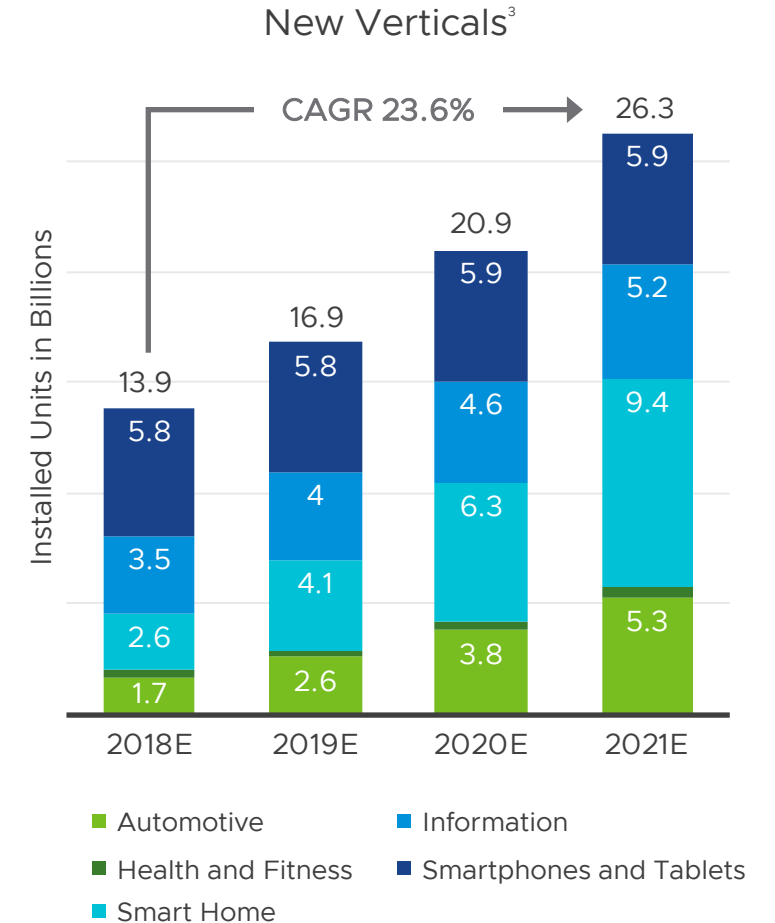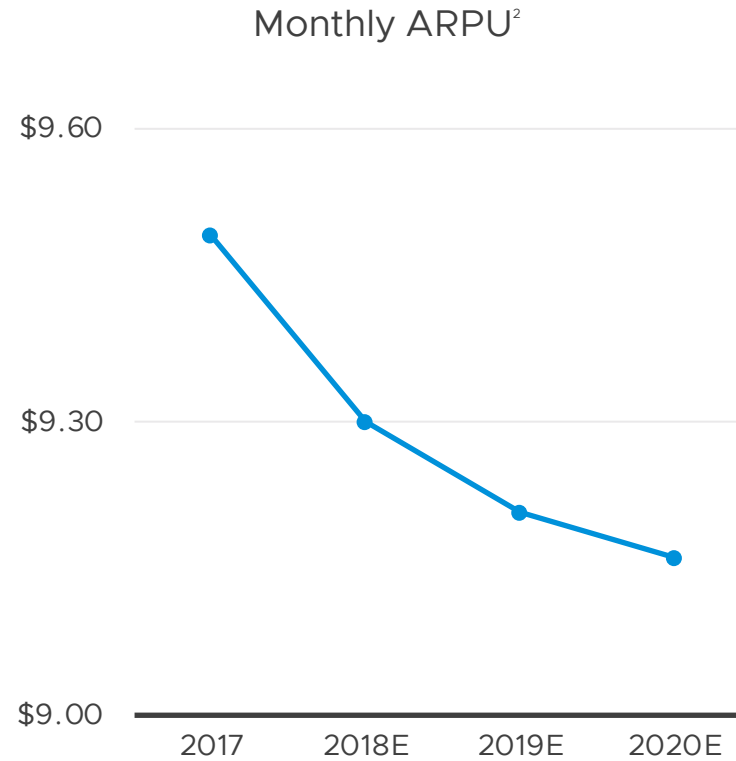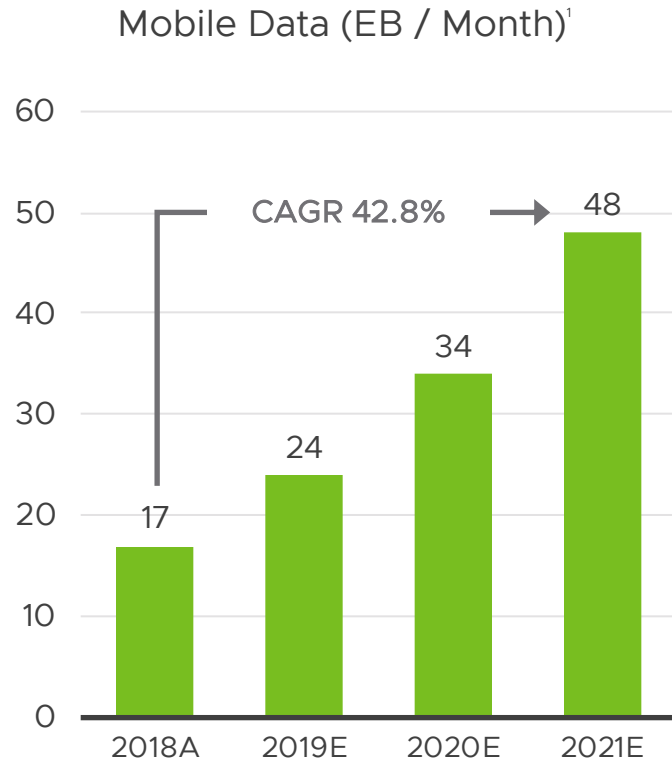## to optimize mobile user experience

資深技術顧問 Kimi Lo

VMware Taiwan

5G 時代的挑戰

5G 時代來臨，電信運營商的嚴峻挑戰

Increasing traffic, decreasing ARPU and demanding new verticals. Must increase capacity efficiently and meet dynamic service requirements of demanding new verticals

Mobile Data (EB / Month)[1]

CAGR 42.8%

- 2018A: 17
- 2019E: 24
- 2020E: 34
- 2021E: 48

Monthly ARPU[2]

- 2017
- 2018E
- 2019E
- 2020E

New Verticals[3]

CAGR 23.6%

Installed Units in Billions

	Automotive	Smart Home	Information	Smartphones and Tablets	Total
2018E	1.7	2.6	3.5	5.8	13.9
2019E	2.6	4.1	4	5.8	16.9
2020E	3.8	6.3	4.6	5.9	20.9
2021E	5.3	9.4	5.2	5.9	26.3

- Automotive
- Information
- Health and Fitness
- Smartphones and Tablets
- Smart Home

企業專網應用

Non-public 5G networks will be a critical building block of your enterprise network strategy

Non-public 5G networks boost the digital transformation of core processes while protecting against industrial espionage.
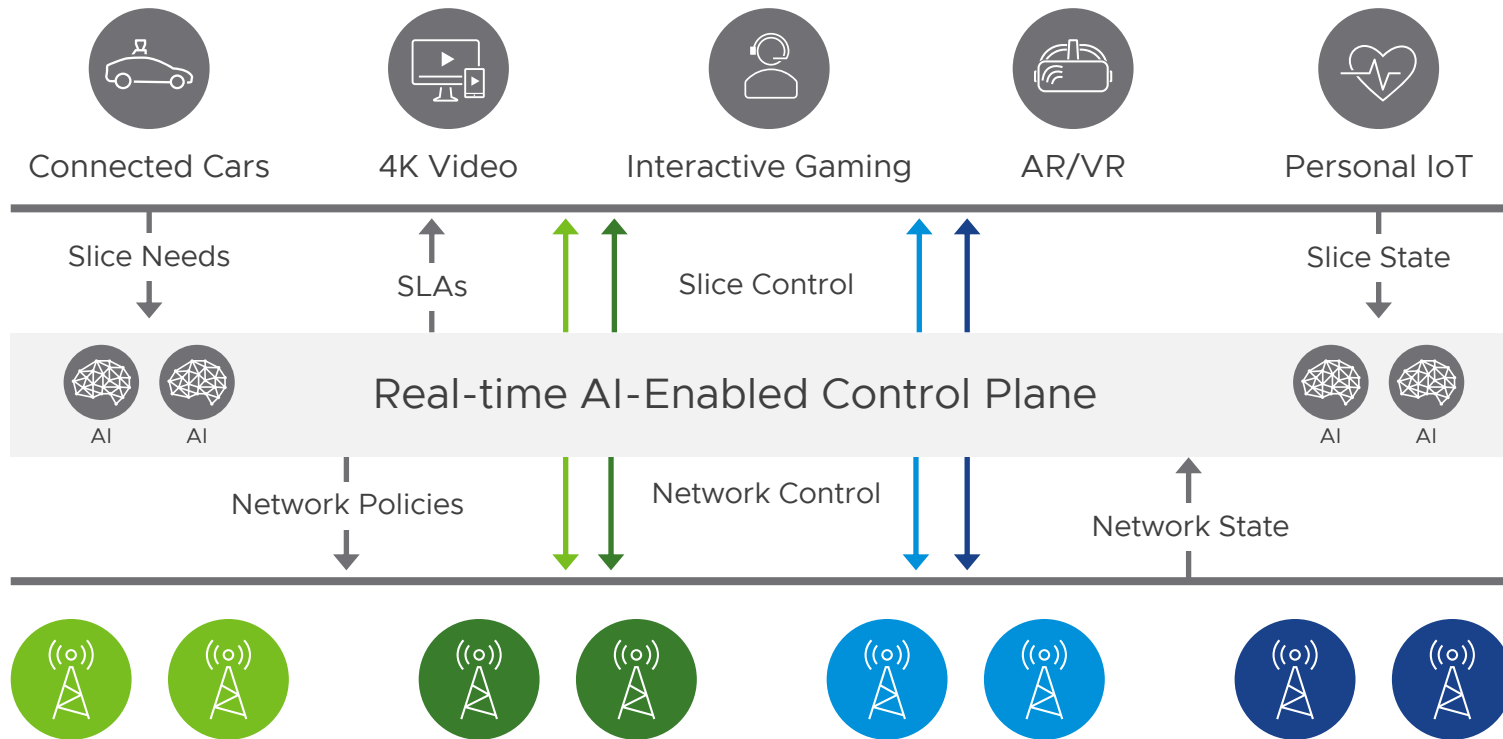
By Forrester Research for Forrester | September 9, 2019 -- 15:41 GMT (23:41 GMT+08:00) | Topic: 5G

Play Sound

Getty

建構一個 AI Enabled 的及時控制引擎
打造使用者的行動新體驗

Slices/apps dynamically request and receive optimized connectivity

Connected Cars   4K Video   Interactive Gaming   AR/VR   Personal IoT

Slice Needs   SLAs   Slice Control   Slice State

AI   AI   Real-time AI-Enabled Control Plane   AI   AI

Network Policies   Network Control   Network State

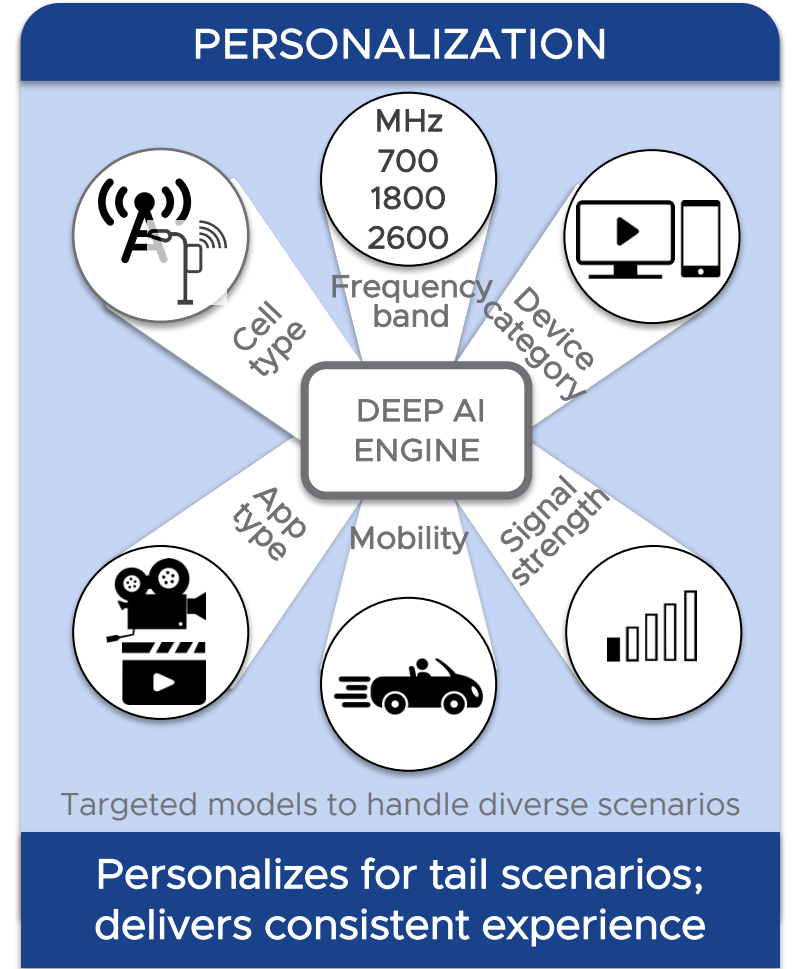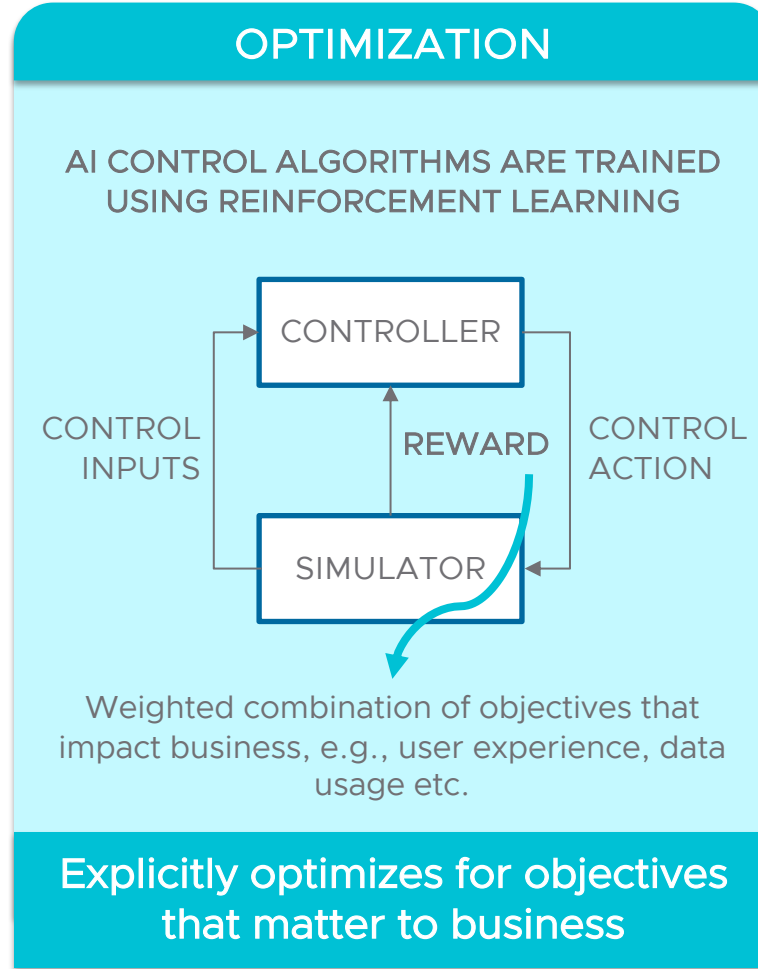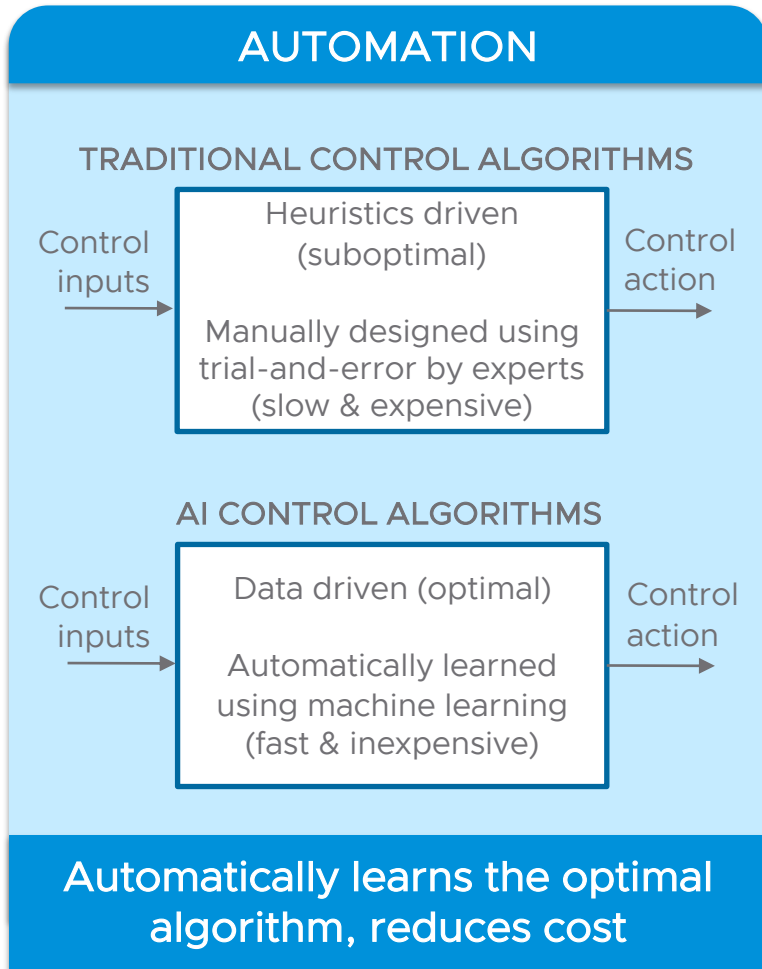Autonomous network control and automation to optimize performance

10x
More new demanding verticals that are dynamically competing for optimal connectivity

10x
5G has 10x more control variables than LTE

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為什麼要使用人工智慧？
Automation, Optimization and Personalization at Scale

AUTOMATION

TRADITIONAL CONTROL ALGORITHMS

Control inputs → Heuristics driven (suboptimal) / Manually designed using trial-and-error by experts (slow & expensive) → Control action

AI CONTROL ALGORITHMS

Control inputs → Data driven (optimal) / Automatically learned using machine learning (fast & inexpensive) → Control action

Automatically learns the optimal algorithm, reduces cost

OPTIMIZATION

AI CONTROL ALGORITHMS ARE TRAINED USING REINFORCEMENT LEARNING

CONTROL INPUTS → CONTROLLER → REWARD → CONTROL ACTION → SIMULATOR

Weighted combination of objectives that impact business, e.g., user experience, data usage etc.

Explicitly optimizes for objectives that matter to business

PERSONALIZATION

MHz 700 1800 2600
Frequency band

Cell type

Device category

DEEP AI ENGINE

App type

Mobility

Signal strength

Targeted models to handle diverse scenarios

Personalizes for tail scenarios; delivers consistent experience

真實環境中的問題

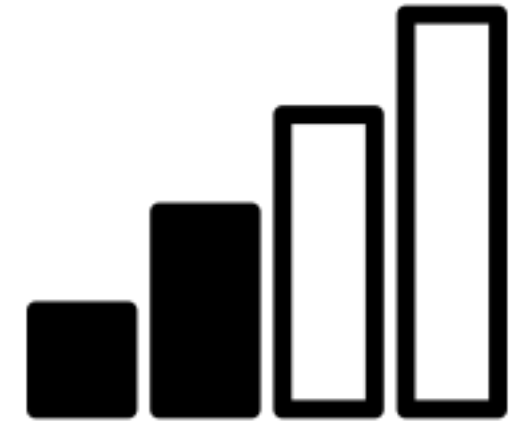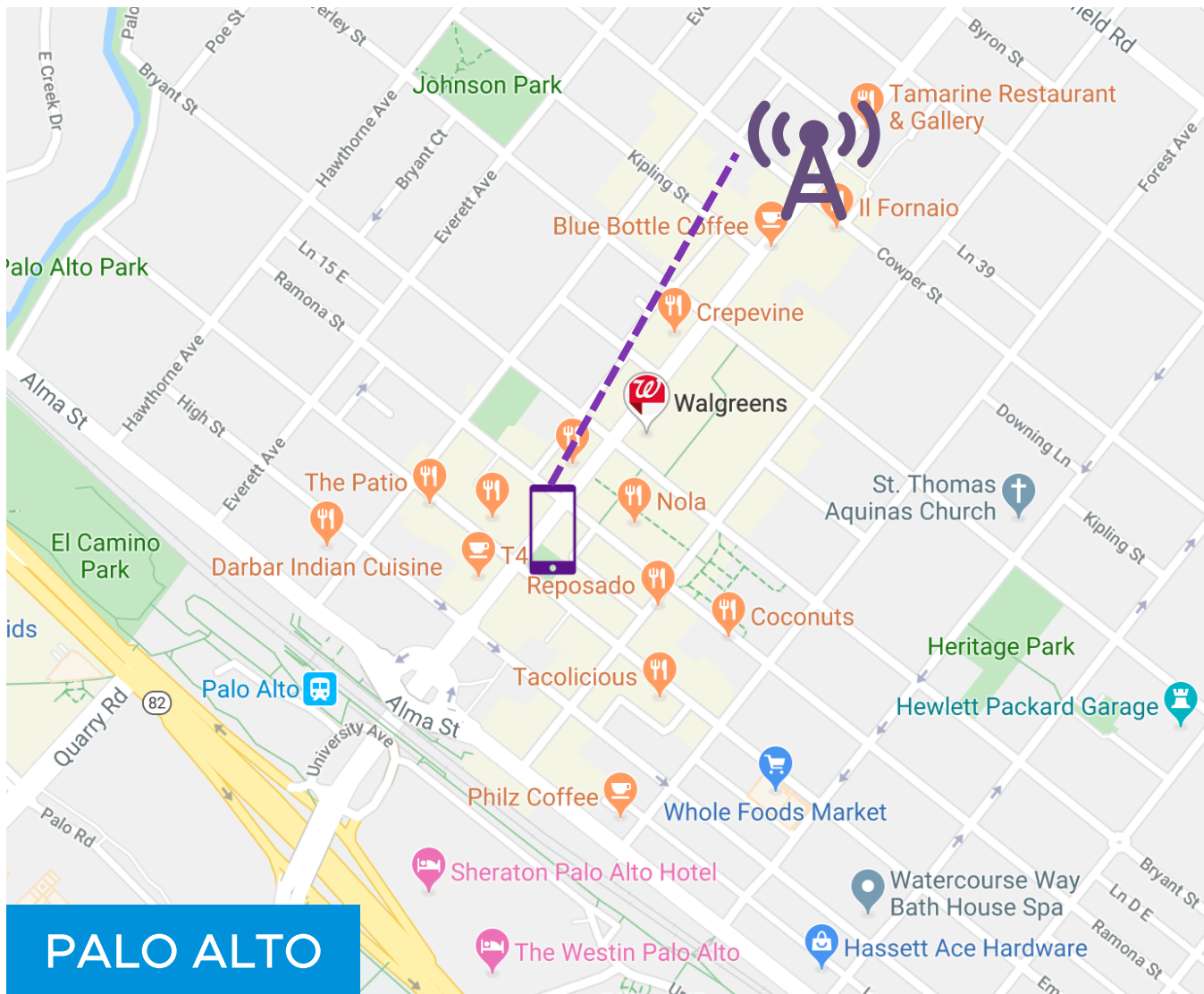# 案例 #1: 手機收訊良好穩定但卻無法發送 email 或 po 臉書 ？

BRISBANE

Signal levels are good & stable

Yet sending emails or posting to social media is extremely slow

Problem occurs during both peak and off-peak hours

LTE network congestion is not the issue

案例 #2: 訊號穩定但特定基地台連線卻在固定時段發生頻繁的線上影音播放延遲？

PALO ALTO

Signal is moderate & stable

Video plays fine all afternoon but exhibits mysterious stall patterns in the evenings

Long (> 20s each)
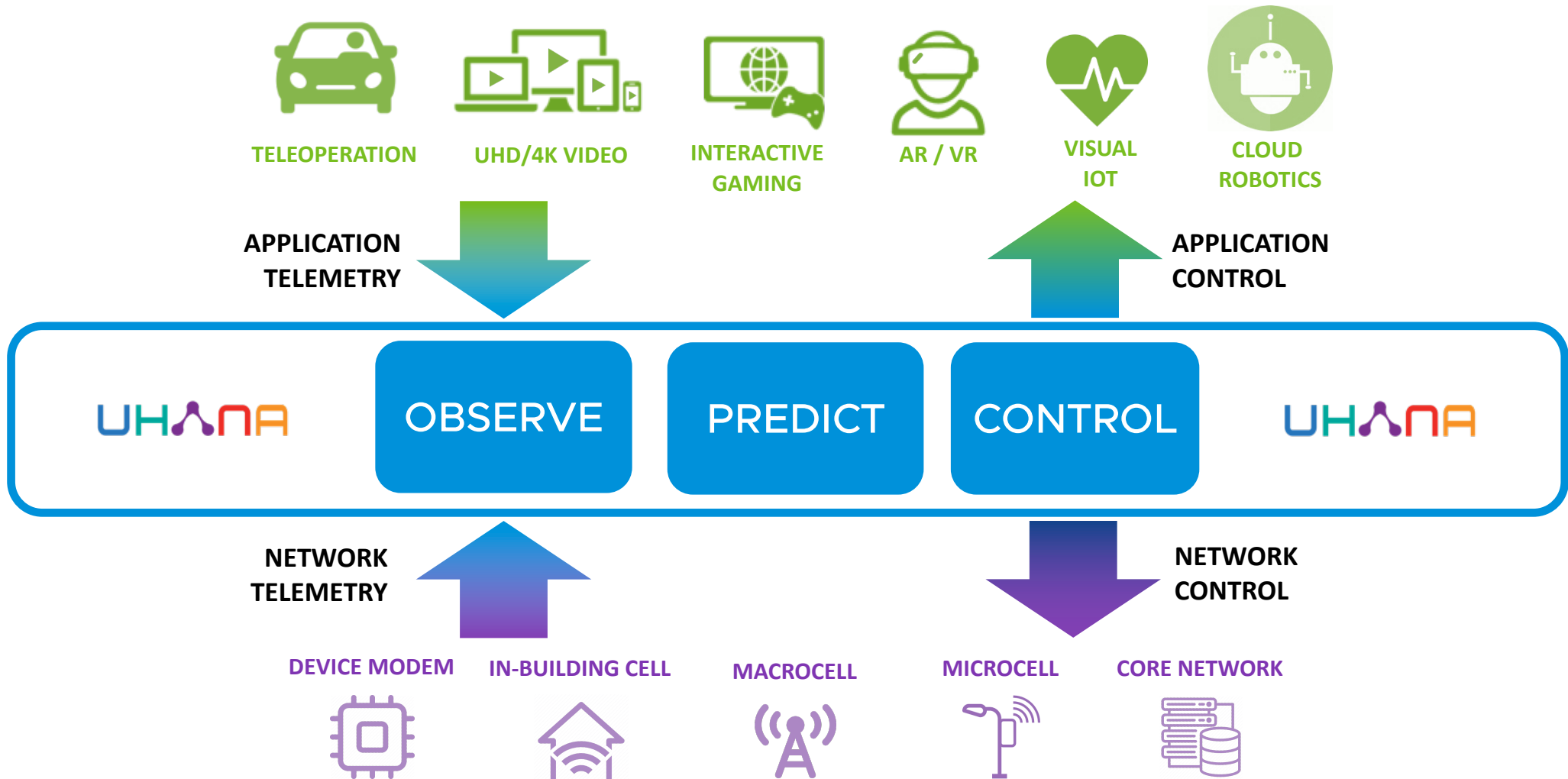Frequent (every ~5 mins)
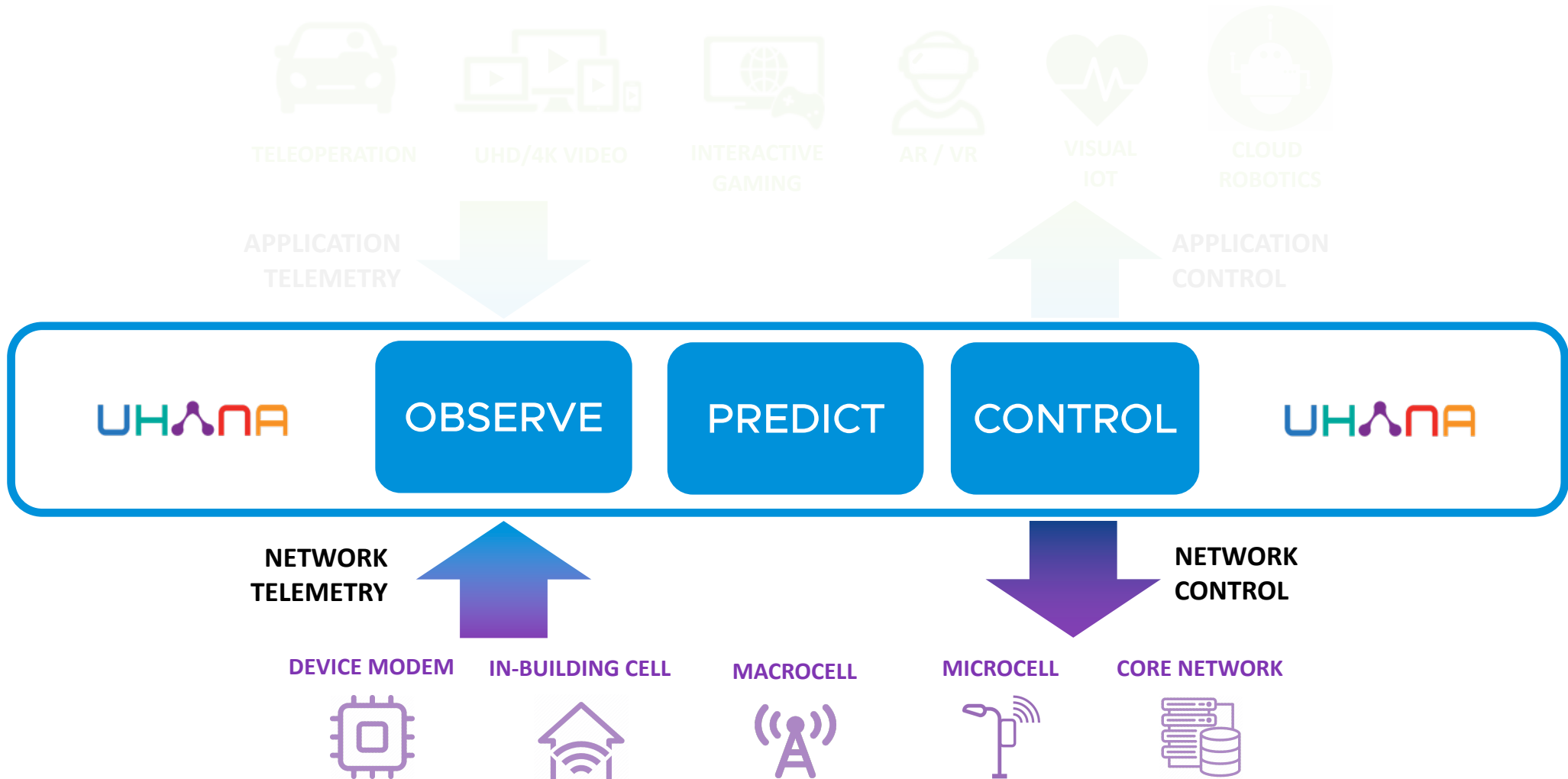Occur roughly at similar times every day
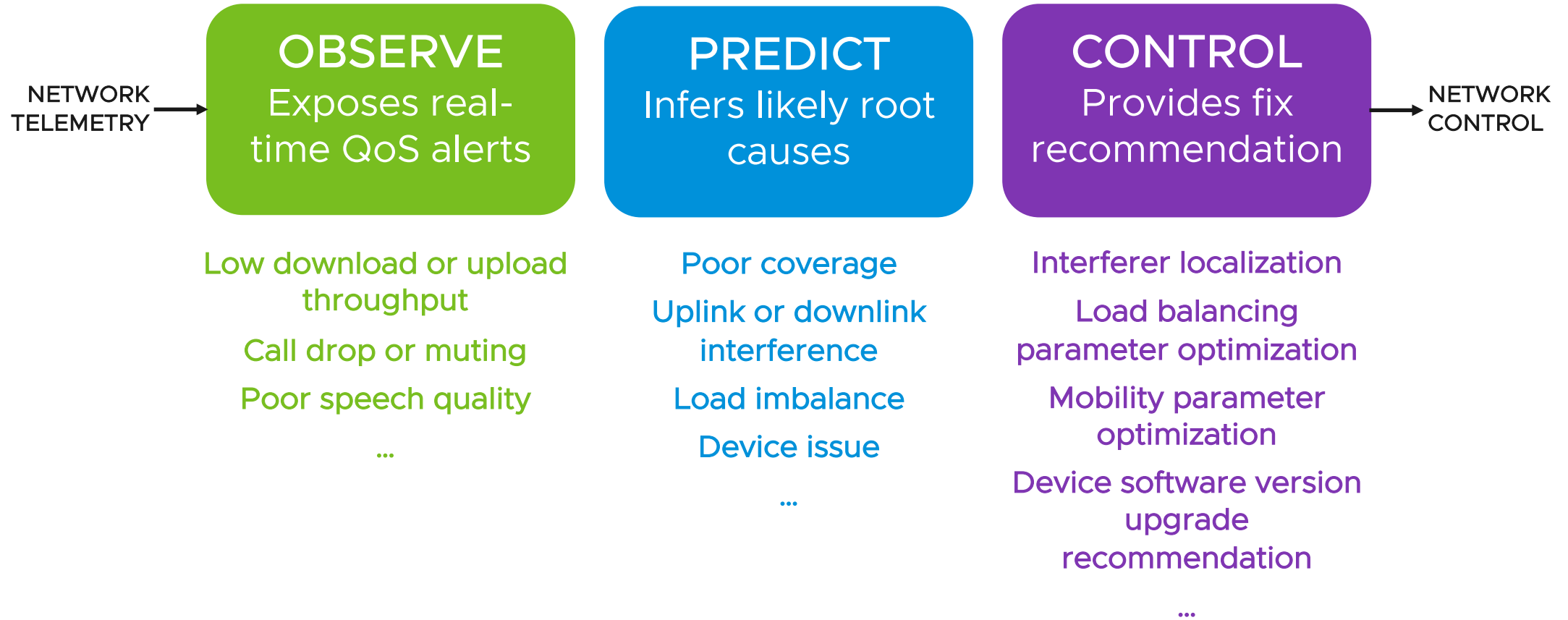Do not occur on any neighboring cell

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如何利用機器學習解決難題

訓練模型

TELEOPERATION   UHD/4K VIDEO   INTERACTIVE GAMING   AR / VR   VISUAL IOT   CLOUD ROBOTICS

APPLICATION TELEMETRY

APPLICATION CONTROL

UHANA   OBSERVE   PREDICT   CONTROL   UHANA

NETWORK TELEMETRY

NETWORK CONTROL

DEVICE MODEM   IN-BUILDING CELL   MACROCELL   MICROCELL   CORE NETWORK

使用網路度量資料進行網路控制

TELEOPERATION UHD/4K VIDEO INTERACTIVE GAMING AR / VR VISUAL IOT CLOUD ROBOTICS

APPLICATION TELEMETRY

APPLICATION CONTROL

UHANA OBSERVE PREDICT CONTROL UHANA

NETWORK TELEMETRY

NETWORK CONTROL

DEVICE MODEM IN-BUILDING CELL MACROCELL MICROCELL CORE NETWORK

vmware®

Example: 即時網路告警

NETWORK TELEMETRY →

OBSERVE
Exposes real-time QoS alerts

PREDICT
Infers likely root causes

CONTROL
Provides fix recommendation

→ NETWORK CONTROL

Low download or upload throughput

Call drop or muting

Poor speech quality

...

Poor coverage

Uplink or downlink interference

Load imbalance

Device issue

...

Interferer localization

Load balancing parameter optimization

Mobility parameter optimization

Device software version upgrade recommendation

...

案例 #1: 手機收訊良好穩定但卻無法發送 email 或 po 臉書 ？

External Interferer on the UPLINK

BRISBANE

4G

Signal levels are good & stable

Yet sending emails or posting to social media is extremely slow

Problem occurs during both peak and off-peak hours

LTE network congestion is not the issue

SELECTION

Range

All ▼

TIME

Window

Custom ▼

Custom start

Oct 12, 2019 8:05 AM

Custom end

Oct 12, 2019 9:05 AM

Live update ⬤

Go

Share | Reset Selection

Alerts

| Below 61 | 61 - 183 | 183 - 366 | 366 - 488 | Over 488 |

Map | Satellite — Reset Map

Enoggera · Ascot · Eagle · The Gap · Bowen Hills · Fortitude Valley · Murarrie · Mount Coot-Tha · New Farm · Cannon Hill · South Brisbane · Carina · Toow · Taringa · Coorparoo · Kenmore Hills · rookfield · Indooroopilly · Greenslopes · Carina Heights

Map data ©2019 · Terms of Use · Report a map error
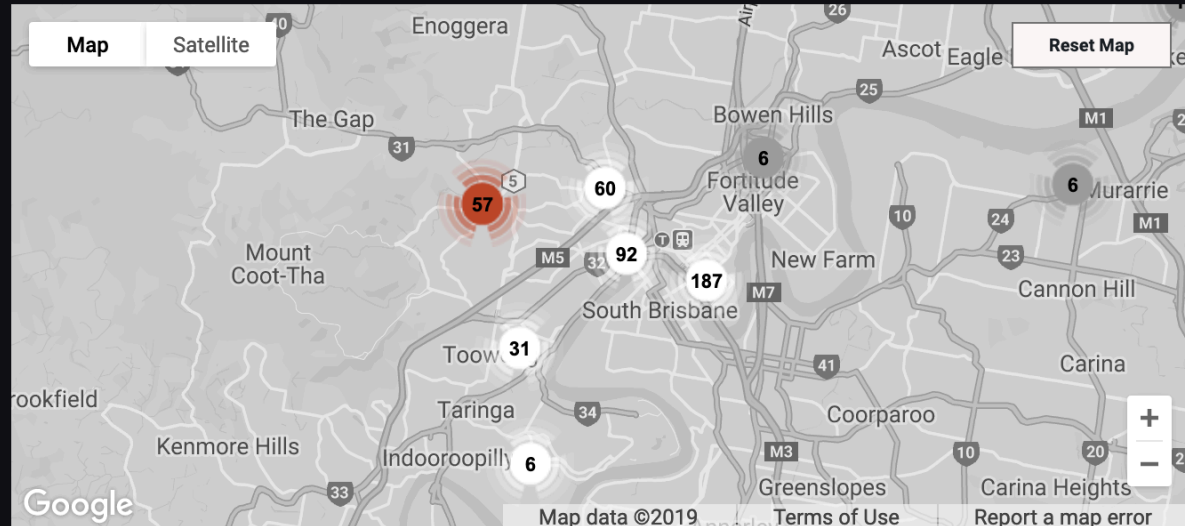
Search Alerts

Alerts 101	**Affected Entities** 69	**Impacted Sessions** 605	**Percent Impacted** 16.4%

Impacted Sessions Breakdown

53 Uplink Interference
552 Load Imbalance

EXAMPLE

Alert ID	Symptom	Duration	Affected Entities	Session Impact	Percent Impacted	Root Cause	Actions
LI_LESS_OFFLOAD-AGVEFM3-DL_THP	Poor downlink throughput	4d	AGVEFM3, AGVEAM3, AGVEBM3, AGVEEM3	552	59.4%	Load imbalance: Traffic offloading not enough	～ | 👁
ULINTF_UNKNOWN-SBNEFM1-DL_THP	Poor downlink throughput	3d 22h	SBNEFM1	16	12.6%	Uplink interference: Unknown	～ | 👁
ULINTF_UNKNOWN-SBNKFM1-DL_THP	Poor downlink throughput	3d 22h	SBNKFM1	7	4.4%	Uplink interference: Unknown	～ | 👁
ULINTF_LB-WRFMFM2-DL_THP	Poor downlink throughput	3d 22h	WRFMFM2	7	2.5%	Uplink interference: Unknown	～ | 👁
ULINTF_EXTERNAL-TOLDFM2-DL_THP	Poor downlink throughput	3d 22h	TOLDFM2, TOLDFM1, SLGCFM1, PDGWFM2	5	7.4%	Uplink interference: External	～ | 👁
ULINTF_LB-WRFMFM3-DL_THP	Poor downlink throughput	3d 22h	WRFMFM3	4	1.9%	Uplink interference: Unknown	～ | 👁
ULINTF_EXTERNAL-WRFMFM3-DL_THP	Poor downlink throughput	3d 22h	WRFMFM3, WIKYFM2, CPZNFBA, WRFMFM2	3	0.8%	Uplink interference: External	～ | 👁

101 Alerts

Previous 1 2 3 4 5 Next

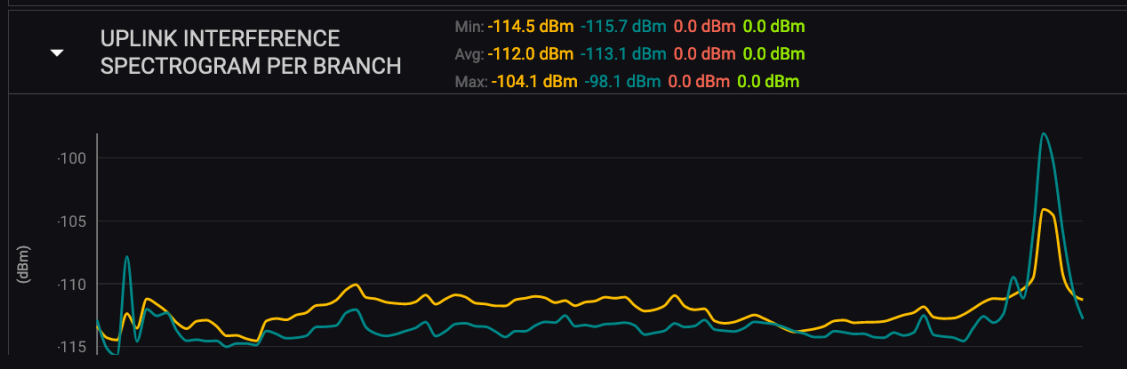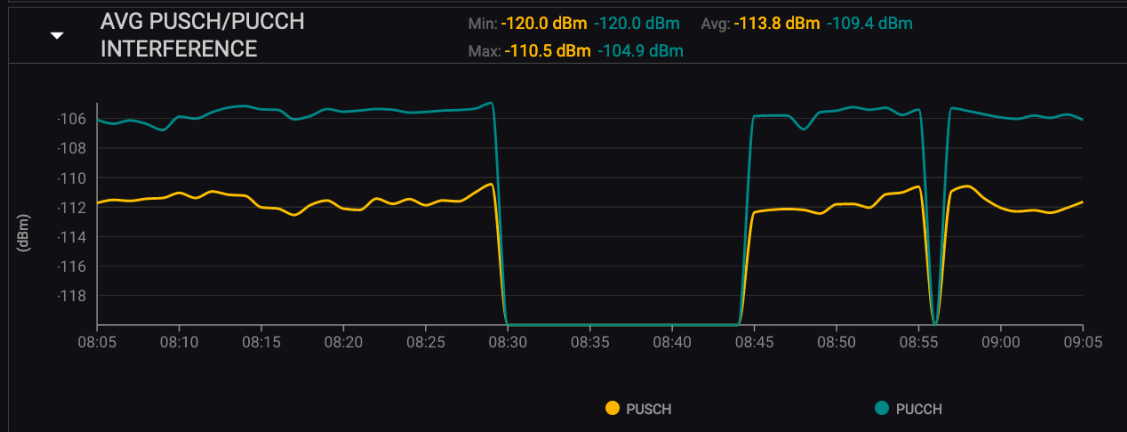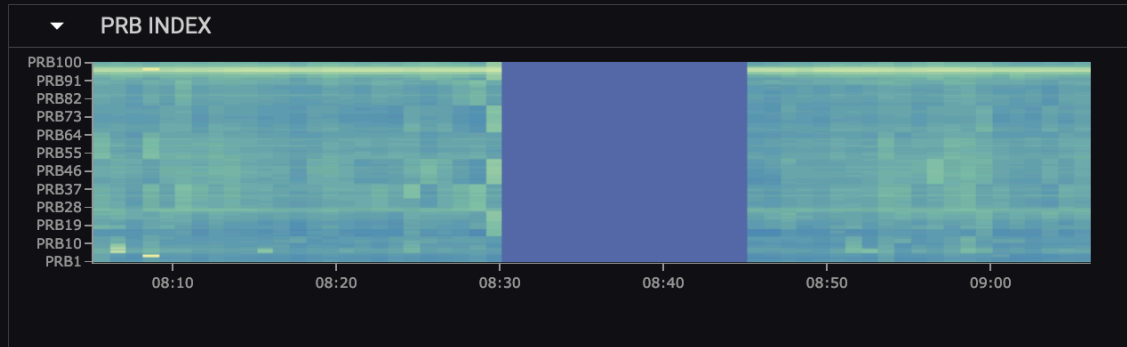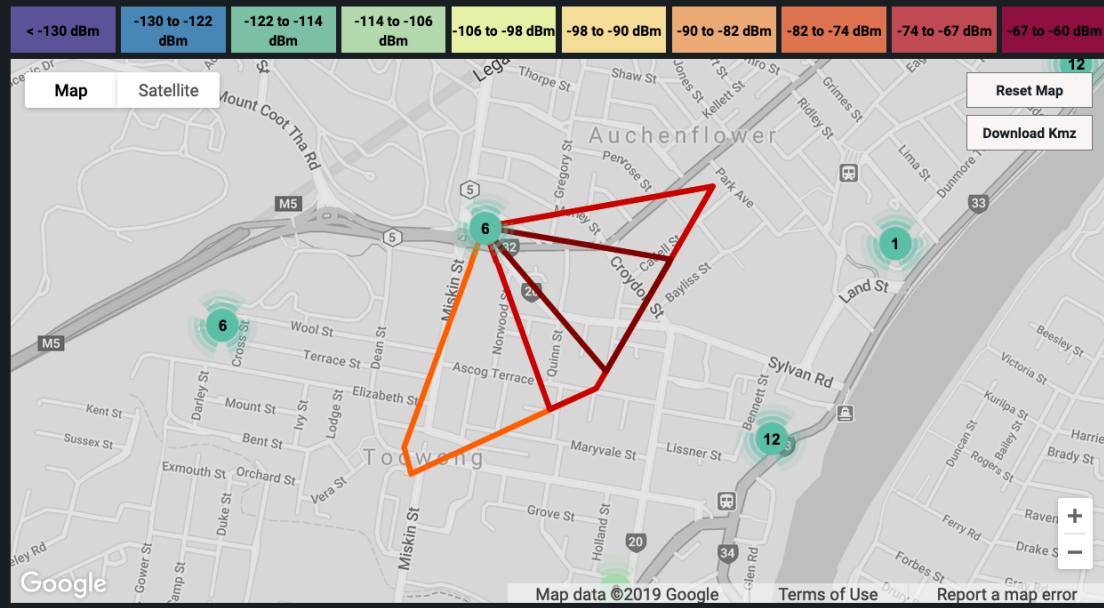**Alert ID**   ULINTF_EXTERNAL-TOLDFM2-DL_THP
Root Cause   Uplink interference: External
Impacted Sessions   5 (7.8%)
Affected Cells   NTQYFM2,   NTQYFM3,   TOLDFM1,   **TOLDFM2,**   PDGWFM2,   SLGCFM1
Duration   October 8th 2019, 2:01 pm - October 12th 2019, 12:59 pm
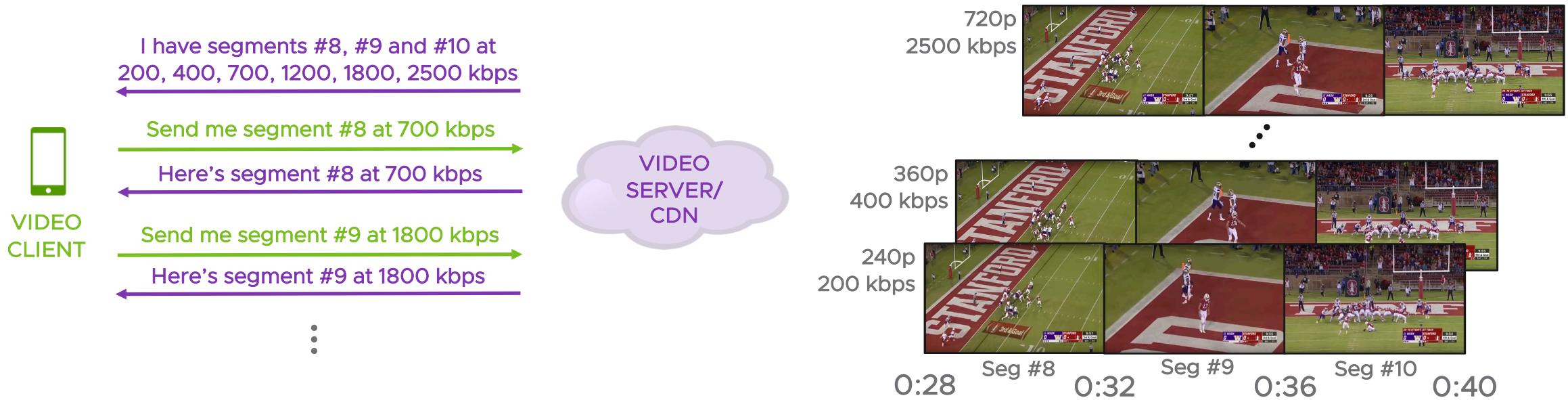
ROOT CAUSE ANALYSIS

Uplink interference: External

FIX RECOMMENDATION #1

Turn off external interference at the location shown. More red the polygon, more likely is the interferer to be found there.

< -130 dBm	-130 to -122 dBm	-122 to -114 dBm	-114 to -106 dBm	-106 to -98 dBm	-98 to -90 dBm	-90 to -82 dBm	-82 to -74 dBm	-74 to -67 dBm	-67 to -60 dBm

Video Adaptive Bitrate (ABR) 的優化選擇

I have segments #8, #9 and #10 at
200, 400, 700, 1200, 1800, 2500 kbps

Send me segment #8 at 700 kbps

Here's segment #8 at 700 kbps

Send me segment #9 at 1800 kbps

Here's segment #9 at 1800 kbps

VIDEO
CLIENT

VIDEO
SERVER/
CDN

720p
2500 kbps

360p
400 kbps

240p
200 kbps

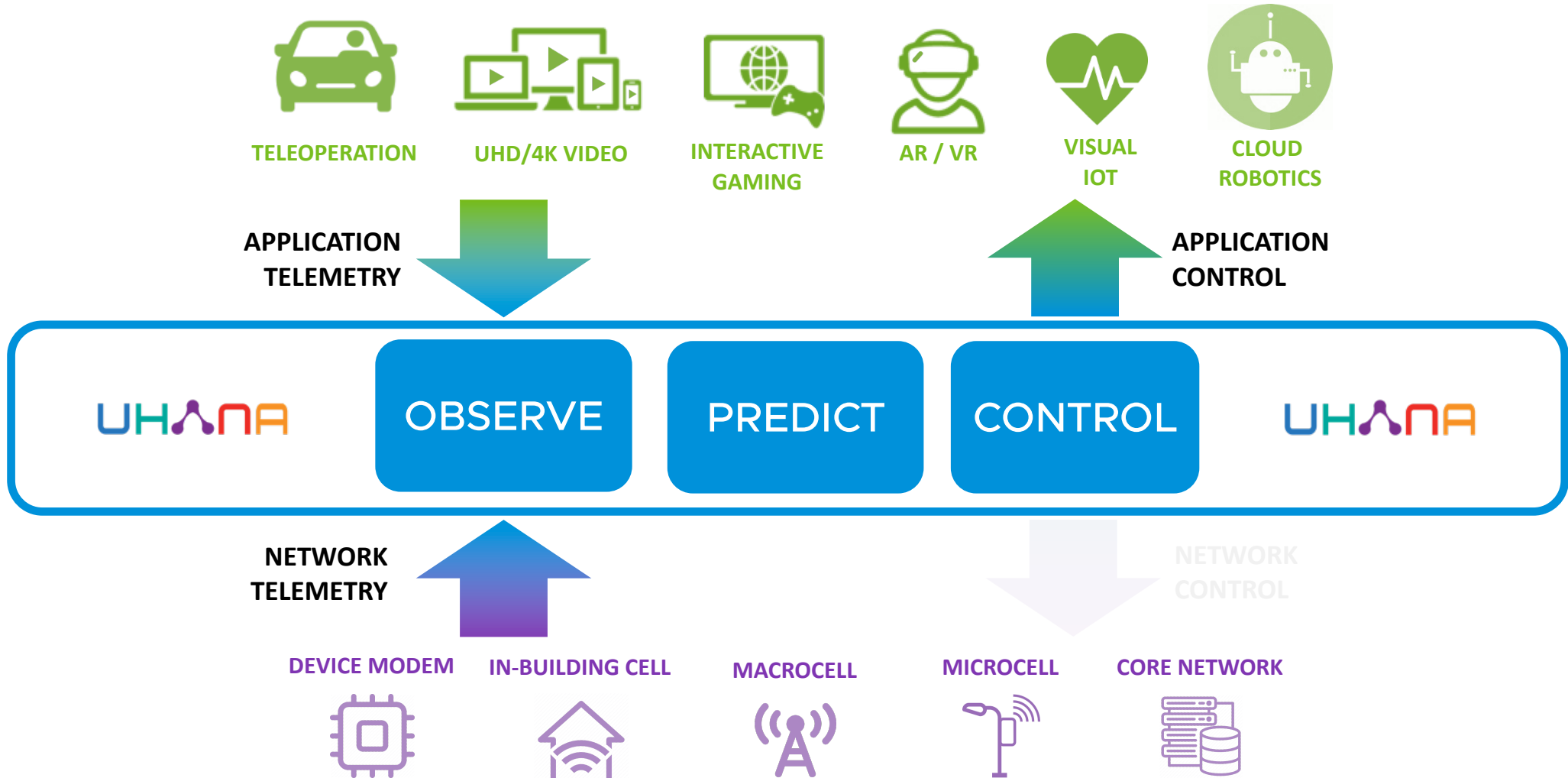0:28   Seg #8   0:32   Seg #9   0:36   Seg #10   0:40

Select *Bitrate* for every segment so as to maximize the cumulative user quality of experience

$$\Sigma_{\text{(all video segments in a session)}} \left[\text{Bitrate} \quad \mu \text{ Stall Duration} \quad \beta \text{ Bitrate Switch} \right]$$

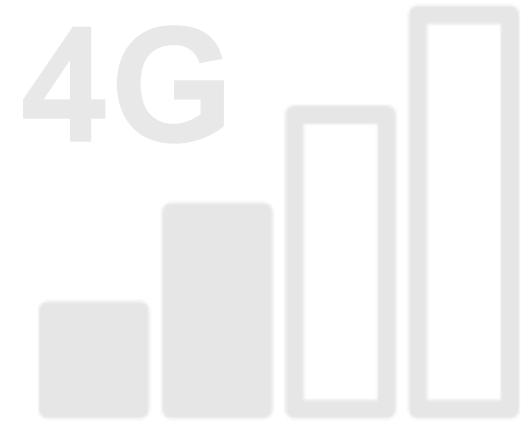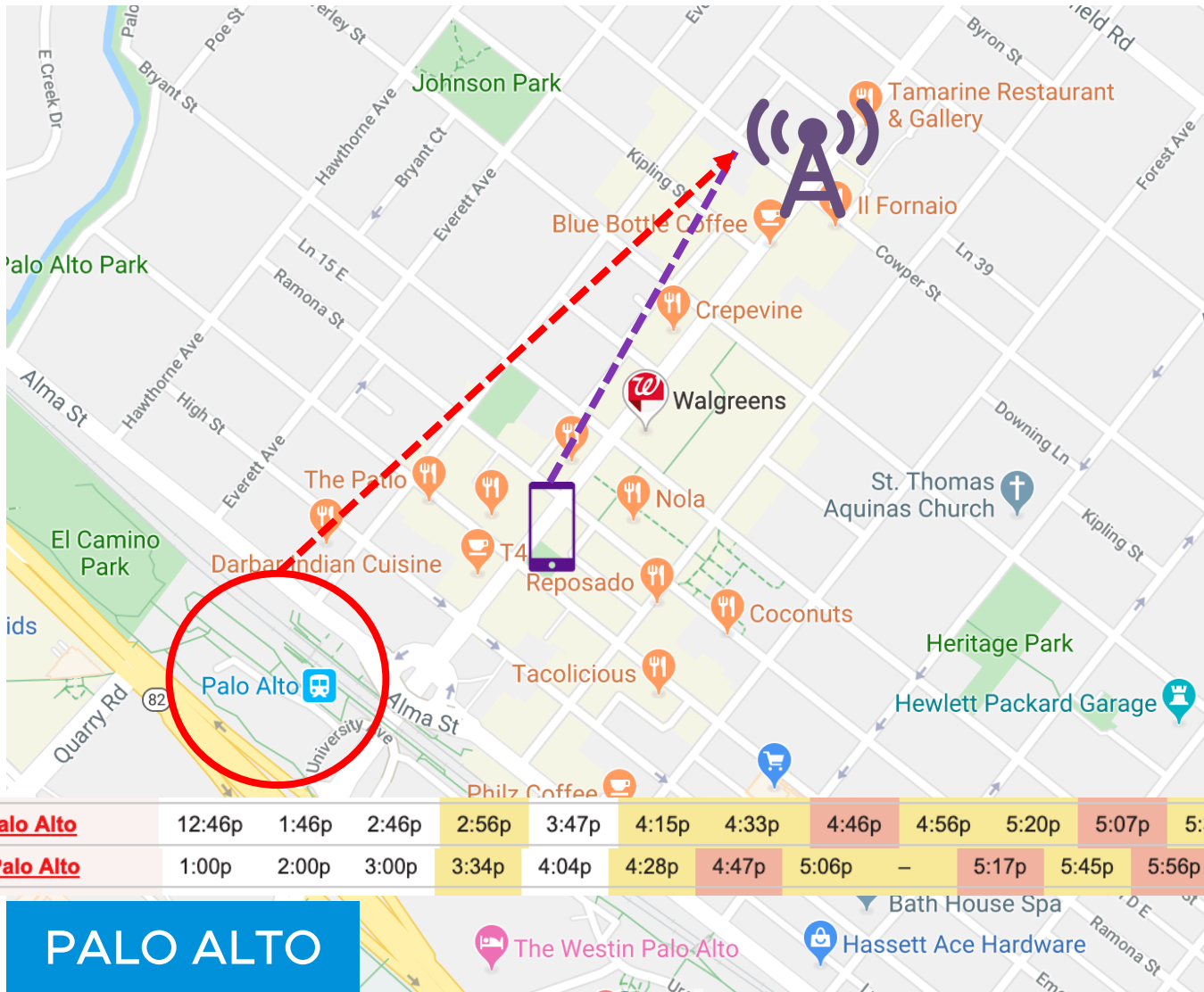Increasing bitrate => Better video quality but higher risk of video stall and penalty for switching

使用應用程式與網路度量控制應用程式

TELEOPERATION　UHD/4K VIDEO　INTERACTIVE GAMING　AR / VR　VISUAL IOT　CLOUD ROBOTICS

APPLICATION TELEMETRY

APPLICATION CONTROL

UH∧NA　OBSERVE　PREDICT　CONTROL　UH∧NA

NETWORK TELEMETRY

NETWORK CONTROL

DEVICE MODEM　IN-BUILDING CELL　MACROCELL　MICROCELL　CORE NETWORK

Example: 網路感知的影片 Adaptive Bitrate (ABR) 優化

NETWORK & APPLICATION TELEMETRY →

OBSERVE
Monitor network QoS and video QoE

PREDICT
Predict video throughput

CONTROL
Select video bitrate

→ APPLICATION CONTROL

Uhana 將傳統 ABR 演算法置換成深度學習神經網路

TRADITIONAL APPROACH

Throughput

Buffer

...

Start at **fixed quality** (level 3)

If *buffer* < **low threshold** (10s)
OR > **high threshold** (40s):
Don't change quality

Else: Select highest quality
< **fraction** (75%) of *throughput*

Bitrate

Heuristics driven
Suboptimal video quality of experience

Hardcoded
Performs poorly in challenging scenarios

Handcrafted using trial and error
Slow and expensive to design

UHANA APPROACH

Throughput

Buffer

...

Bitrate

Data driven
Near optimal video quality of experience

Personalized
Performs well in all scenarios

Machine trained using deep learning
Fast and inexpensive to design

通用性與最佳化的難題

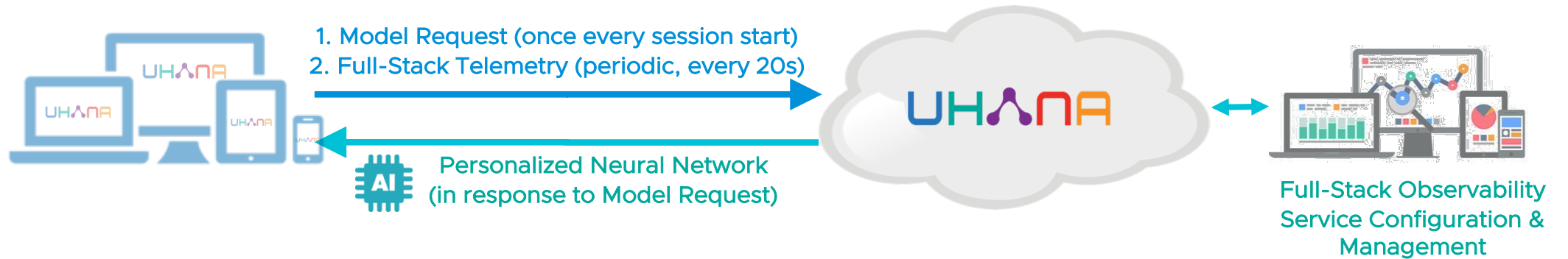| LONG-TERM STATE	SHORT-TERM STATE
Stationary over minutes or more	**Vary across video segments**
Device Type Connectivity Type Live or On Demand Content Type Mobility Regime …	Recent Throughputs Recent Download Times Current Buffer Last Bitrate Recent Rebuffering …

Uhana trains a suite of ABR models, each personalized (optimized) for a specific long-term scenario

Tablet, WiFi, VoD, Low Mobility, …

Phone, LTE, Live, High Mobility, …

TV, WiFi, VoD, High Mobility, …
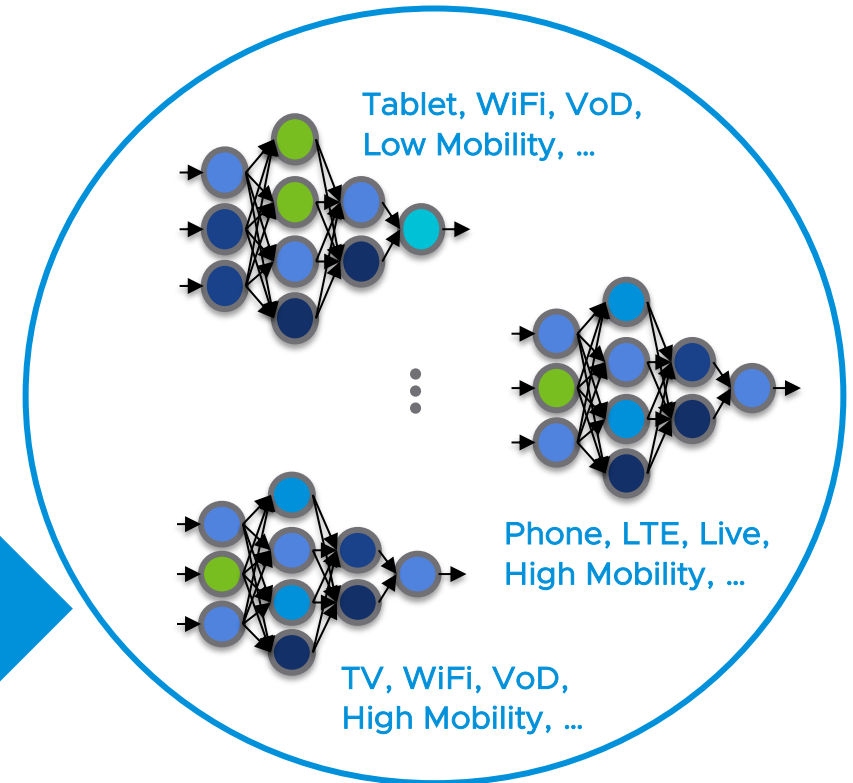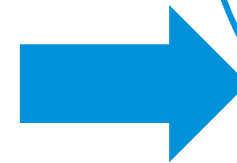
持續進化的機器學習模型
Cloud Service for Model Training & Delivery. On-Device SDK for Model Inference.

1. Model Request (once every session start)
2. Full-Stack Telemetry (periodic, every 20s)

Personalized Neural Network
(in response to Model Request)

Full-Stack Observability
Service Configuration &
Management

UHANA SDK

- One-time, easy integration

- Runs customized neural networks tailored for each application session

- Posts periodic telemetry for full-stack observability from the cloud

UHANA CLOUD SERVICE

- Scalable offline model training and real-time model delivery

- Continuously learns & improves without requiring app updates

- Provides fine-grained subscriber-level full-stack observability

Thank You

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