



台灣雲端物聯網產業協會  
Cloud Computing & IoT Association in Taiwan

# What Are Killer 5G Applications?

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Information and Co



# 5G Technology Overview

- Key functional advances
  - Higher throughput: 100 Mbps → 1Gbps
  - Lower latency: 50 msec → 5 msec
  - Massive connectivity: millions of connections
- Operating frequencies
  - Sub-6GHz: First generation
  - mmWave: Second generation → 28, 38, 60 GHz
- Opportunities
  - Hardware components: High-frequency PCB, RF IC, MIMO antenna array
  - Smartphone and related SOC
  - Small cell base station: hole filling supplement → essential building block
  - Private 5G communication system
  - Commercially compelling 5G applications

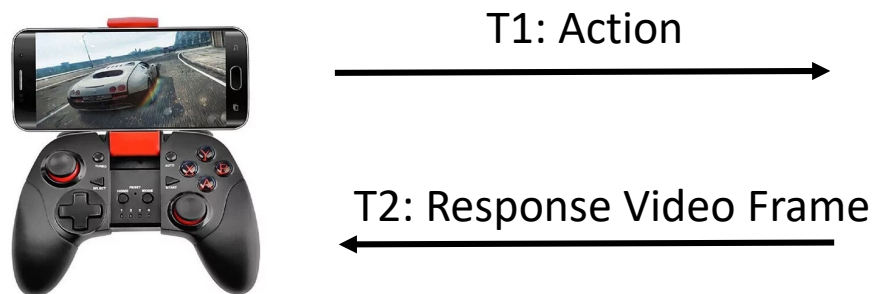


# Killer 5G Applications?

- Litmus test: What can be done on 5G that cannot be done on 4G?
  - Many 5G applications from China, Korea, Japan, and Europe have been proposed, and most of them failed this test
  - Truly compelling ones are hard to come by
- General thinking: applications requiring low-latency feedback loop
  - 1-way: One-way video playback and analysis
  - 1.5-way: On-site real-time streaming of live events
    - Panoramic video for live concerts or sport games
  - 2-way: two-way interaction is involved
    - Tele-operation, including on-line computer gaming
    - Interactive mixed reality

# High Throughput $\neq$ Low Latency

- Transporting data from Tokyo to Kyoto via Shinkansen
  - **Throughput** of shipping 25 10TB HDDs via THSR: **30.8GB/sec**
  - **Latency** of shipping one byte: **2 hours 15 minutes**
- Example latency-sensitive applications: **cloud gaming**



- Acceptable end-to-end latency target for gaming is  **$\sim 30$  msec**
  1. wireless and wired communication latency,
  2. server processing delay, and
  3. video encoding/decoding delay

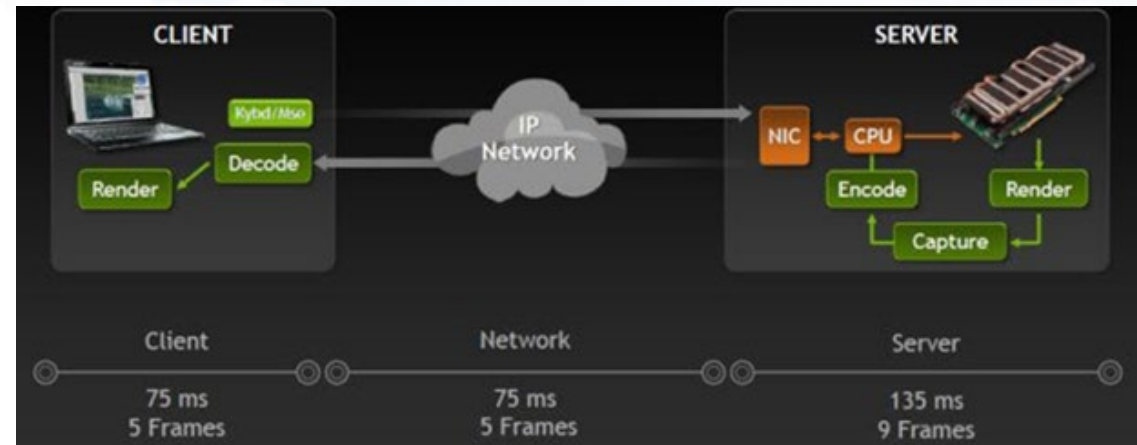


# Tele-Operation

## Remote Drone Piloting



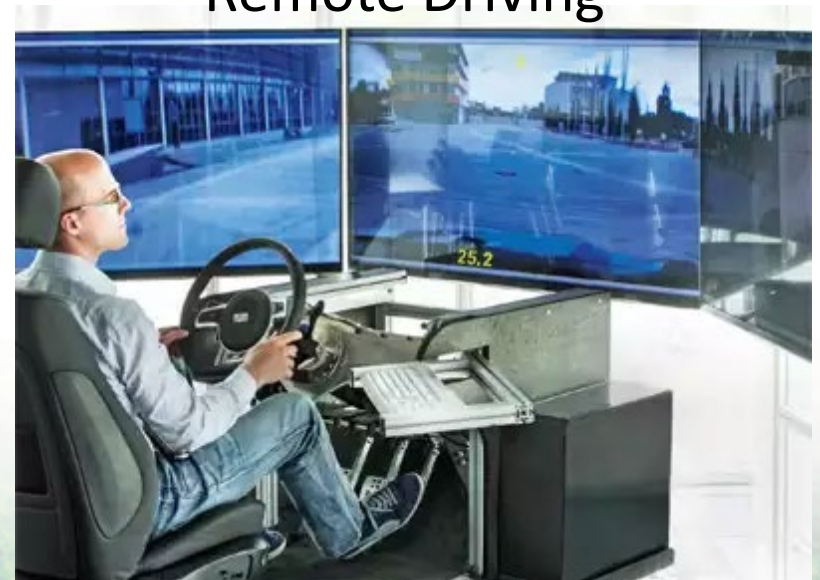
## On-line Computer Game Playing



## Tele-Surgery



## Remote Driving





# Drone-Based Over-Bridge Inspection

- Drone autonomously flies along a bridge to be inspected based on the pre-calculated detailed flight plan.
- Fine-grained payload control is used to take high-quality pictures at inspection targets at the right angle from at least **30 meters away**.

台灣高鐵

Taiwan High Speed Rail





# Under-Bridge Inspection

## ■ Technical Challenges

- How to enable drones to fly without GPS
- How to perform image-based defect analysis under poor lighting conditions



Region of Interest

Poor Lighting Condition



\*5x speed

# 5G+Mixed Reality Drone Racing System





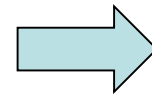
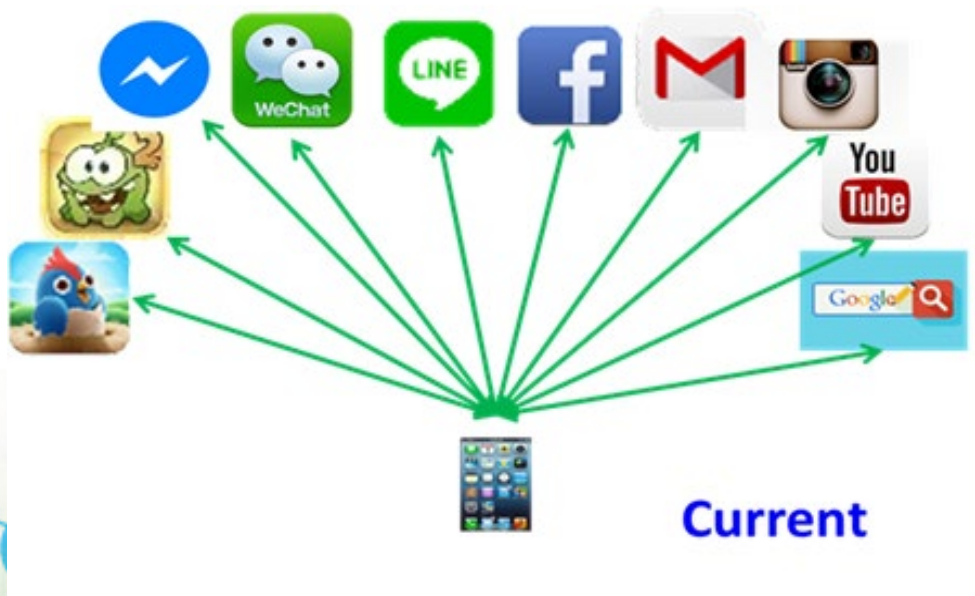
# Cloud Gaming

- Cloud gaming service: Google **Stadia**, Sony's **PlayStation Now** and Microsoft's **Project xCloud**
- Idea: Run computer game applications in the cloud/edge, and stream the game application's image outputs to client devices
  - Also a form of tele-operation
- Original motivations
  - **Thin** gaming console
  - Enable use of more powerful gaming HW in the cloud
- Smartphone game streaming service
  - Hatch (Finland) and Redfinger (China)
  - Innovative value-added auxiliary services



# Virtual Mobility Infrastructure

- Use model: every enterprise employee is given **a virtual smartphone in the cloud** to do office work
  - APPs run in the cloud, experience all sensors in a user's smartphone, and stream their outputs to the user's smartphone.
  - VDI → VMI
- Vision: **One APP for all (Android) APPs**
  - Download and execute → Invoke and execute
  - An app market that **stores** as well as **executes** apps



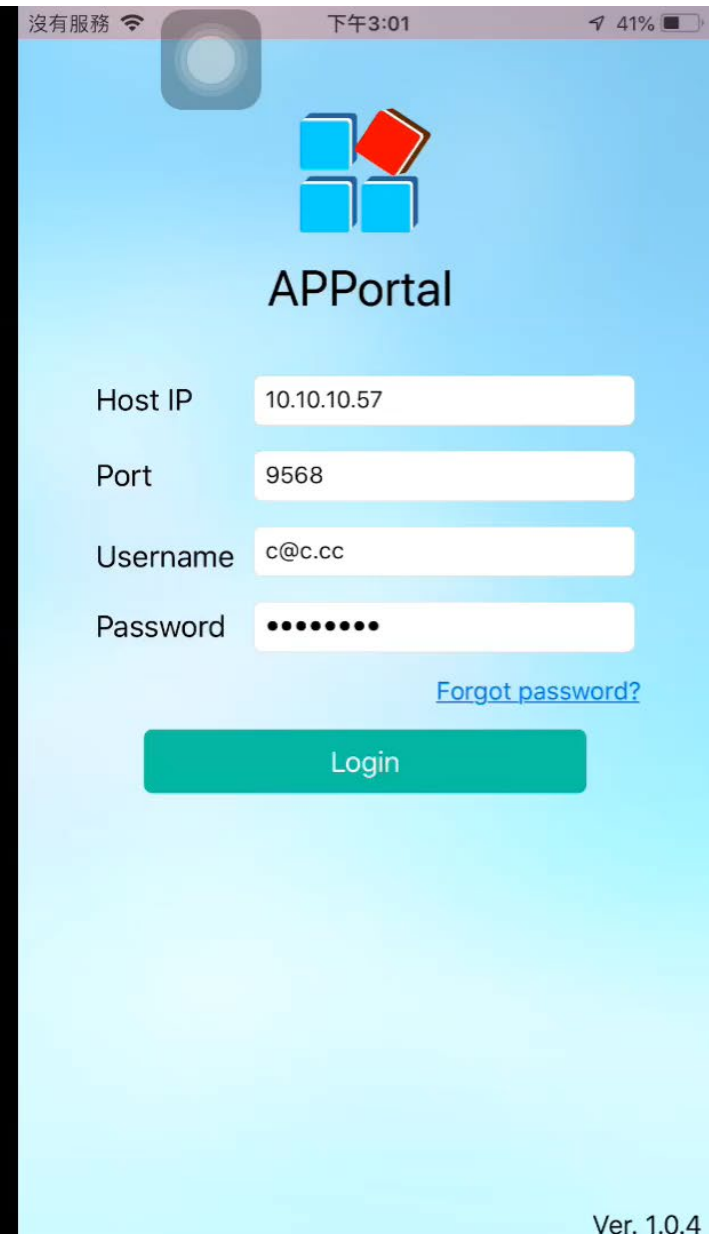


# Smartphone Game Streaming

Physical  
smartphone

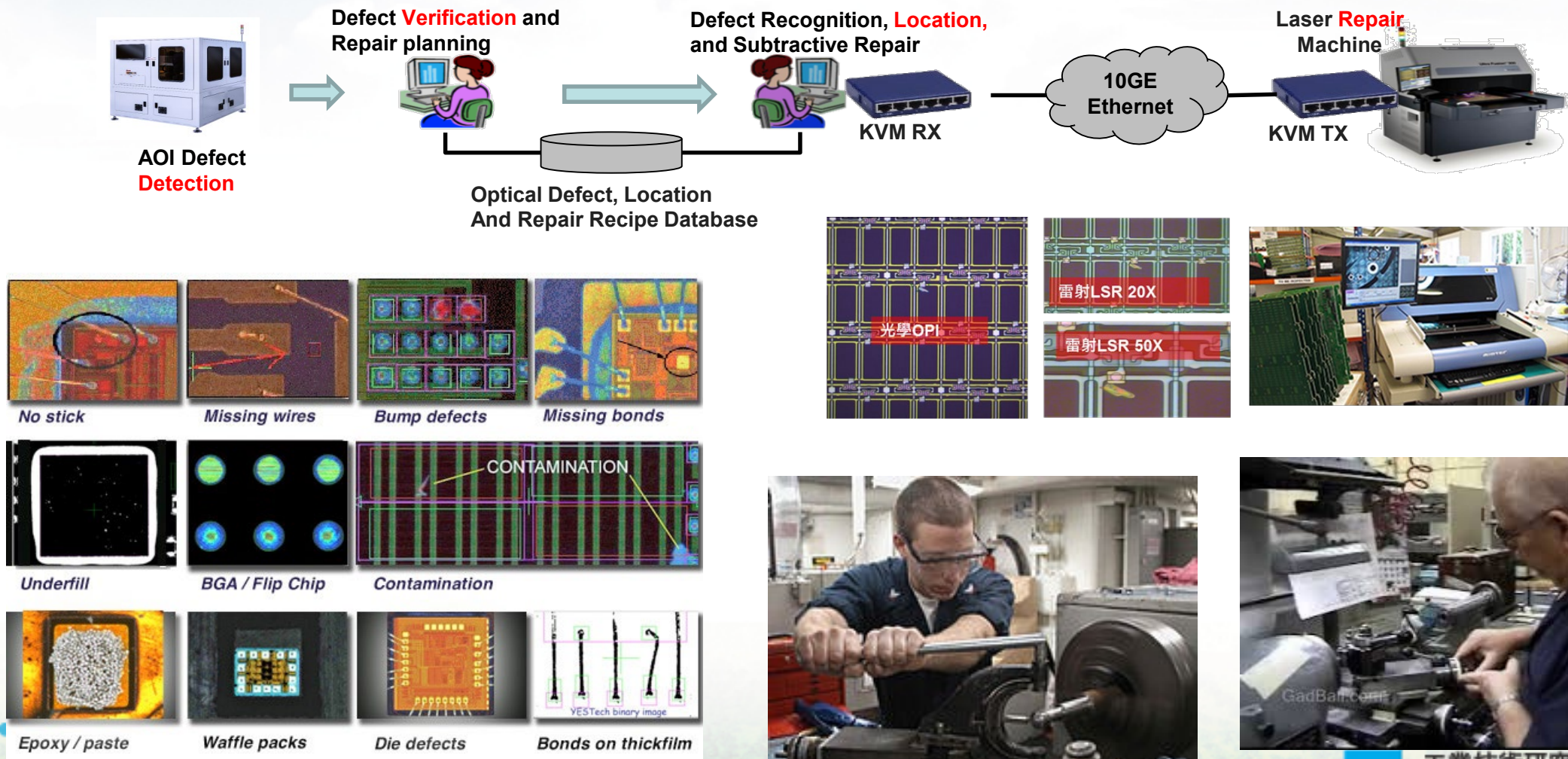


Virtual  
smartphone



# All Optical Inspection in Manufacturing

## Cloud/Edge-based AOI: Decoupling of imaging HW from image analysis SW





# Verification of Manual Assembly SOP

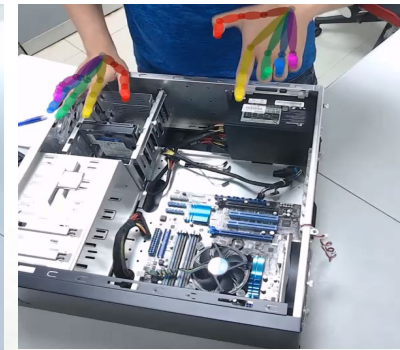
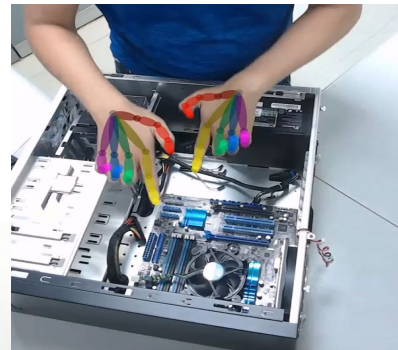
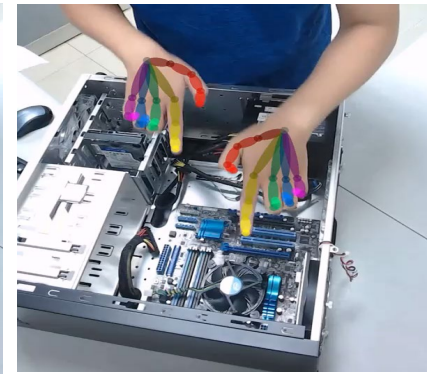
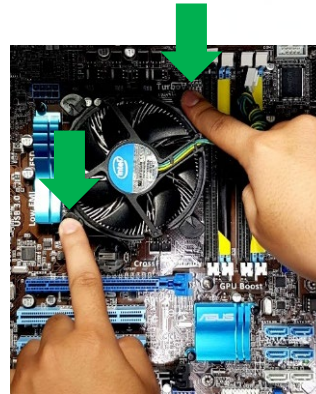
## ■ 將四個旋鈕順時針方向旋轉到底

- ✓ 辨識CPU風扇是否朝上
- ✓ 辨識4個旋鈕是否旋轉到底

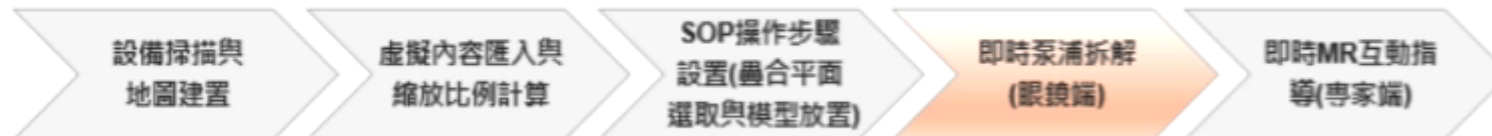


## ■ 以斜對角方式將四個旋鈕向下壓入

- ✓ 辨識雙手食指同時於斜對角旋鈕向下壓入



# MR Guidance for Assembly Operation



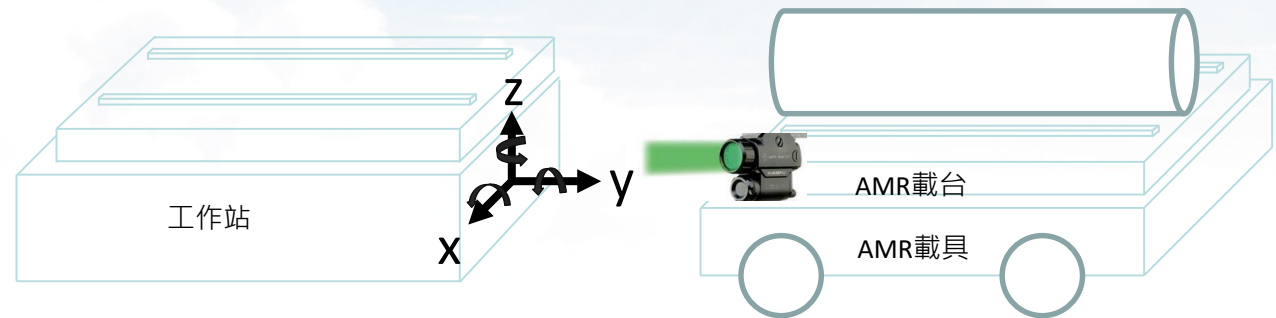
即時泵浦拆解  
(眼鏡端)



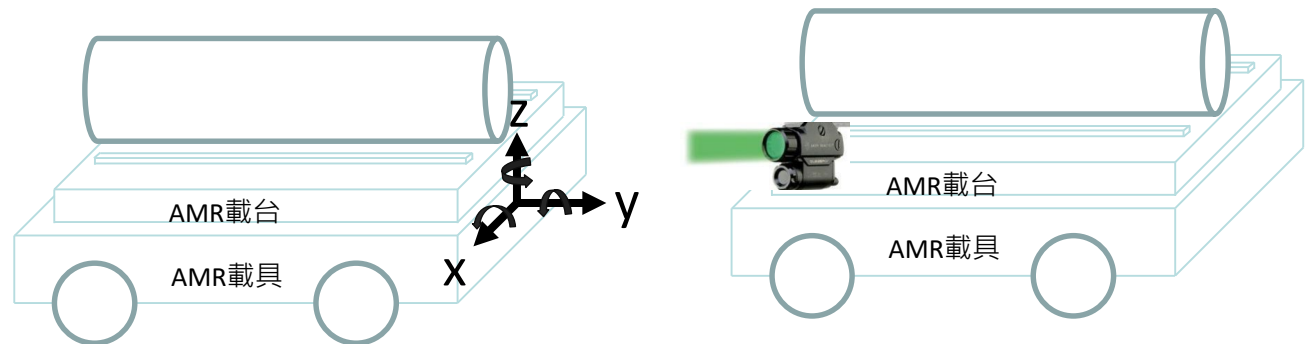


# Precision Docking and Platooning for Autonomous Mobile Robot

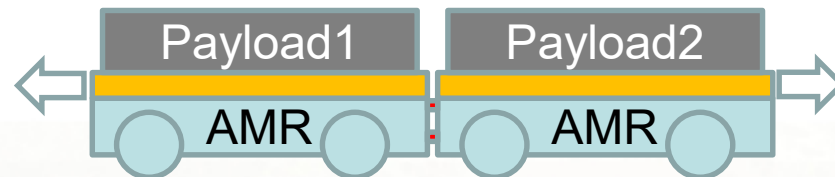
## AMR-Station Docking



## Station-Station Docking



## Multi-AMR Platooning



# Multi-AMR Coordinated Operation: KUKA





# Private 5G Communication System

- Main motivations

- Better QoS or **low latency guarantee**: mainly for smart manufacturing
- Lower cost of ownership

- Uncertainties that remain to be resolved

- How big is the market demand?
- Spectrum availability and (fair) cost
  - Taiwan (4.8-4.9GHz) , Japan (4.6-4.9GHz) , Germany (3.7-3.8GHz), US (3.55-3.7GHz, CBRS)

- Options

1. Rent a dedicated **slice** of a carrier's cellular network at wholesale price (like MVNO)
2. User-owned **cellular** network operating on **public 5G** spectrum
3. User-owned **cellular** network operating on **private 5G** spectrum (4.8-4.9GHz)
4. User-owned **WiFi/4G** network operating on **private 5G** spectrum (4.8-4.9 GHz)

# Summary

- Is 5G overhyped?
  - Which applications are absolutely infeasible without 5G?
    - “My shop-floor network feels lagged.”
  - Which aspects of 5G empower these applications?
  - Private vs. Public 5G
    - Total cost of ownership → spectrum, capital, operation
  - Soul-searching question: **Why is licensed-band WiFi or 4G not good enough?**
- 5G applications with compelling ROI so far
  - Digital transformation for industrial manufacturing
    - Most of them do not really low-latency communications (1-way 10 msec, 2-way 30msec)
  - Cloud/edge gaming
  - Live streaming of events with real-time transformation





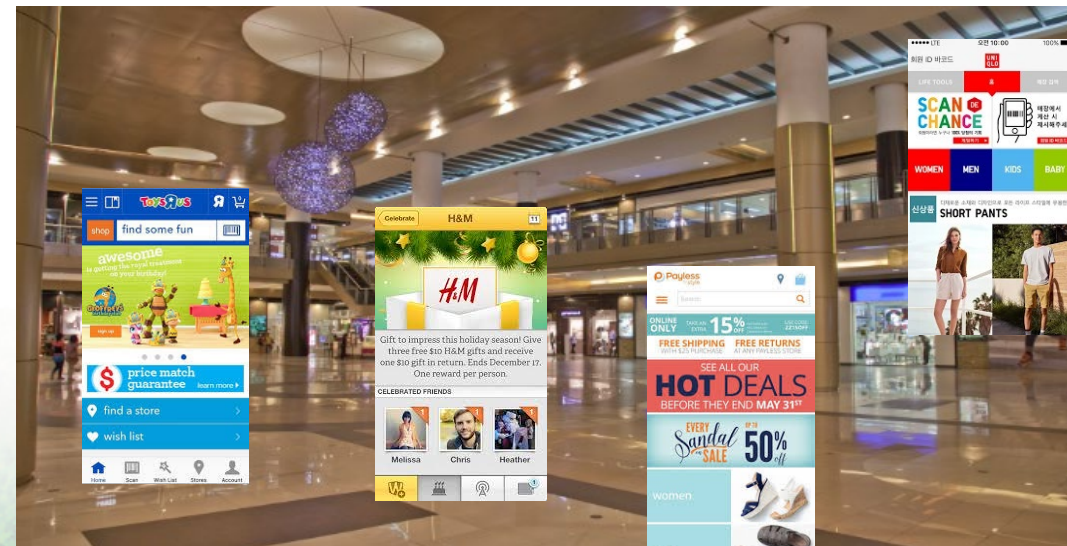
**Thank You!**

**Questions and Comments?**

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# New Service Models

- Address Bring Your Own Device (BYOD) security
  - Only one program on a user's smartphone is allowed to interact with enterprise IT resources.
  - Keeps enterprise data staying inside its cloud data center
  - Enterprise control of enterprise account of messaging app, e.g. LINE
  - 中科院：國產軍用安全手機方案，機敏資料不落地
  - 遠傳電信：2020年提供超過 2,500 員工安全存取內部資料，2021年全公司 7,000 員工使用，並沿伸到中小企業客戶使用
  - 日月光，建準：機敏資料不落地
- Simplify enterprise smartphone app development and deployment
  - Reduces app development cost
  - Enables effortless app trial/promotion
  - Supports **location-based** invocation





# World-Wide 5G Deployment

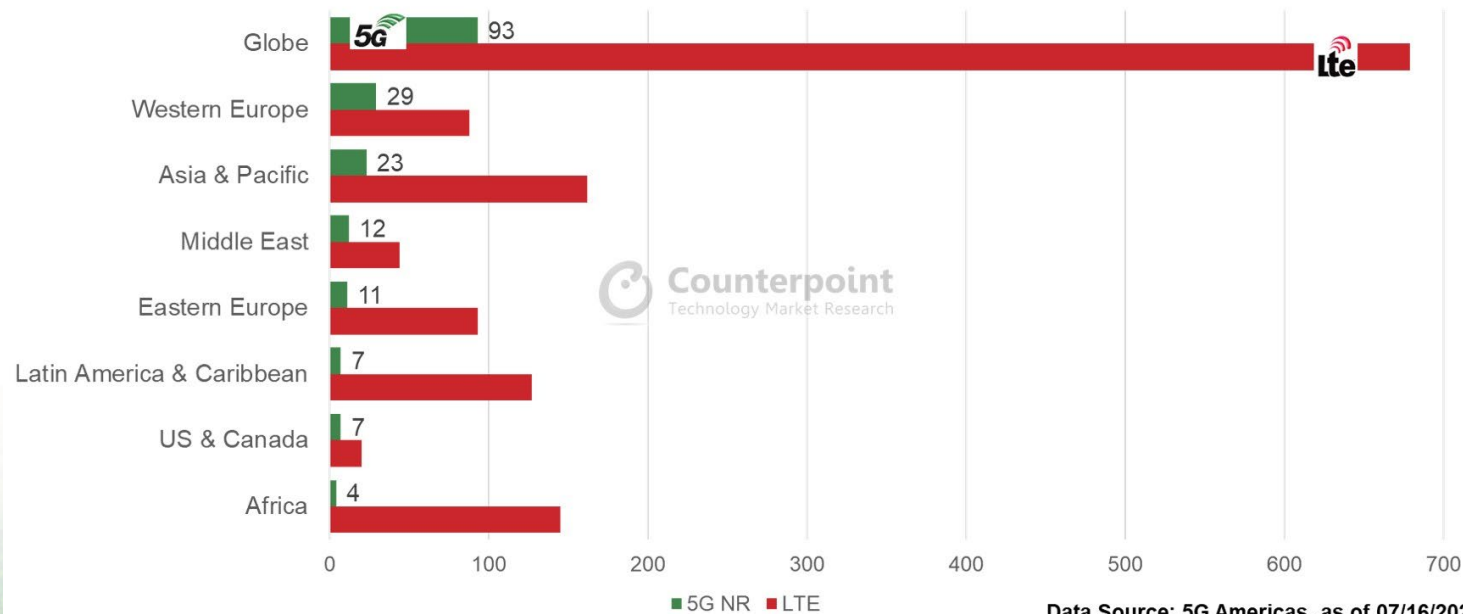
## World-wide 5G Deployment

- 140 telecom operators in 59 countries offer 5G service: 18%
- Only 42 support both Sub-6GHz 與 mmWave
- 5G mobile users penetration rate: 2.44%

## Progress of Major Countries

- South Korea: 17M users, 162K BSs
- US: 39M users and 210K BSs
- China: 300M users; 1000K BSs
- Taiwan: 3M users; 30K BSs

Commercial 5G vs. LTE networks by Region, as of Mid-July 2020



Data Source: 5G Americas, as of 07/16/2020