Gs

Lids@80

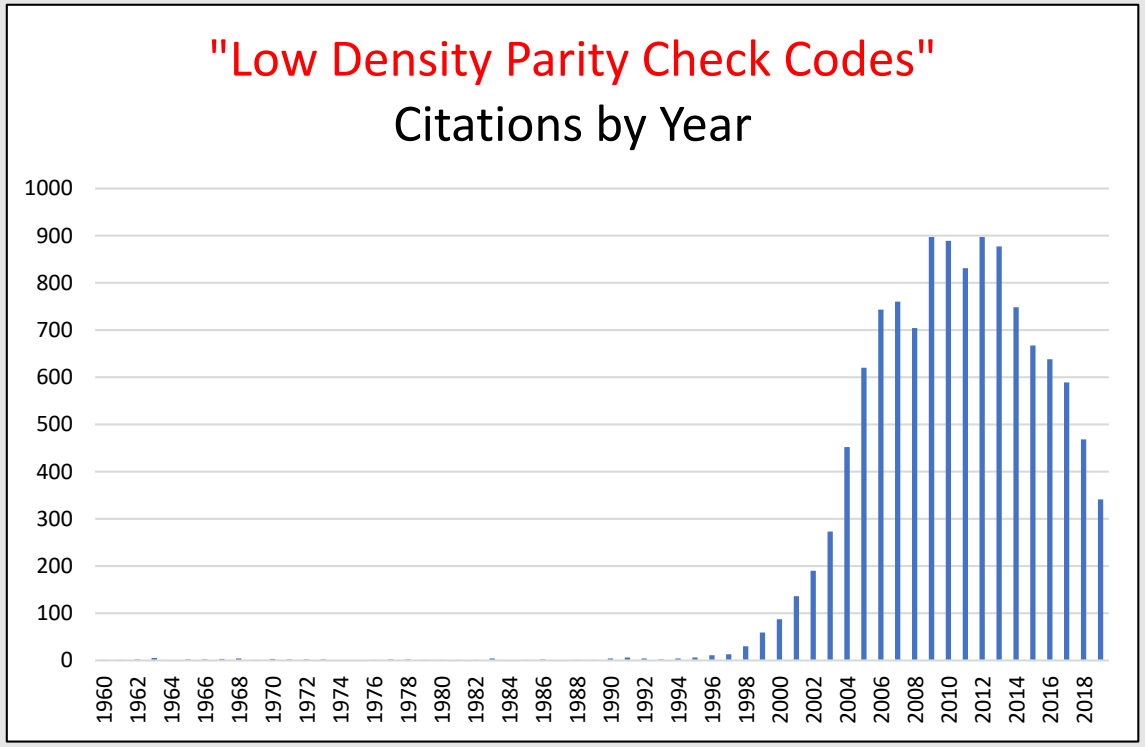
Tom Richardson

A Random walk into Coding and Wireless

- Control (U of T)
- Computer Vision (MIT)
- Math/Communications group (Bell Labs)
  - Holography-data storage

  - Turbo Codes 1993
    - Feedback
    - Dynamical System

  - LDPC 1962



2G → 3G → 4G ： Flarion

- Founded in 2000

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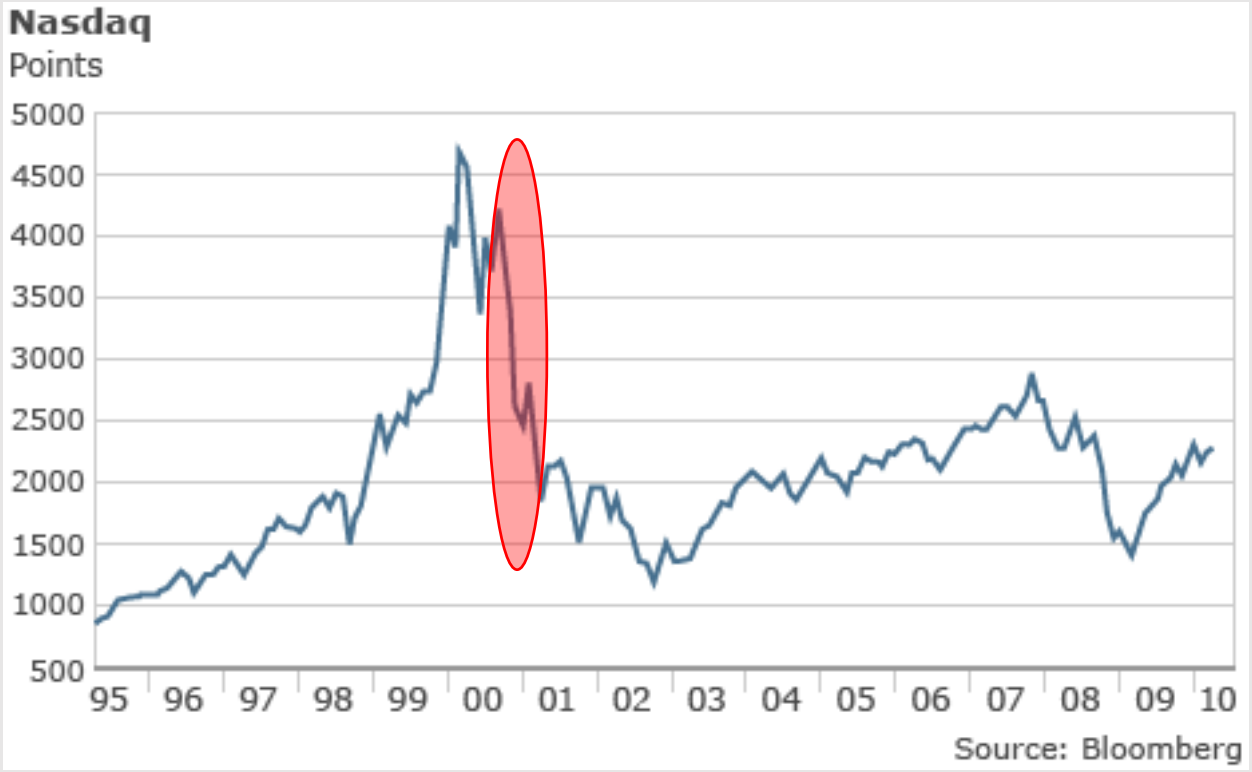


The Internet and Cellular Networks had different DNA

and a Different sense of ‘connected’

Telephony

- Person to person
- Circuit switched
  - End to end reserved connections set up for duration of call
  - Mild reliability, controlled latency
- Cellular = radio link extension

Internet

- Computer to computer
- Packet switched
  - High reliability – except packet drop
- TCP/IP
  - Flow control based on congestion assumption

2G: CDMA as cellular voice solution

- CDMA systems were conceived to efficiently enable cellular voice.
- The basic architecture and mechanisms exploited the statistical properties of voice and aligned with existing phone network architecture.

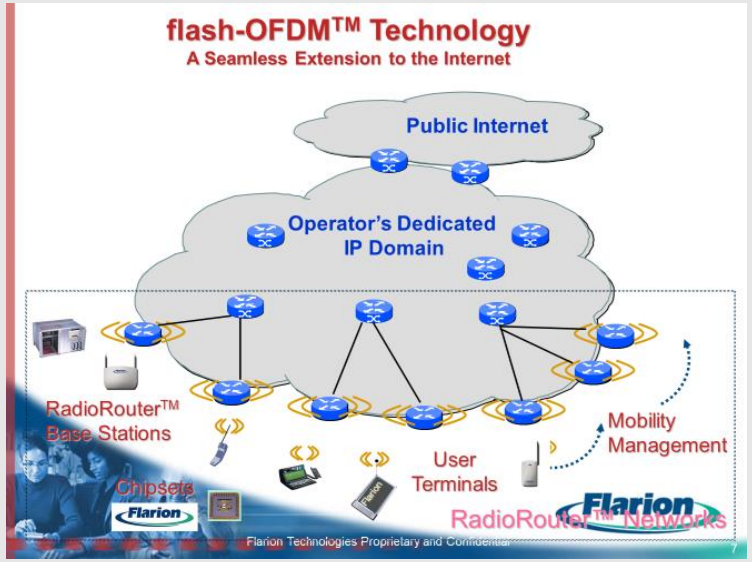
IS 95 Defining characteristics

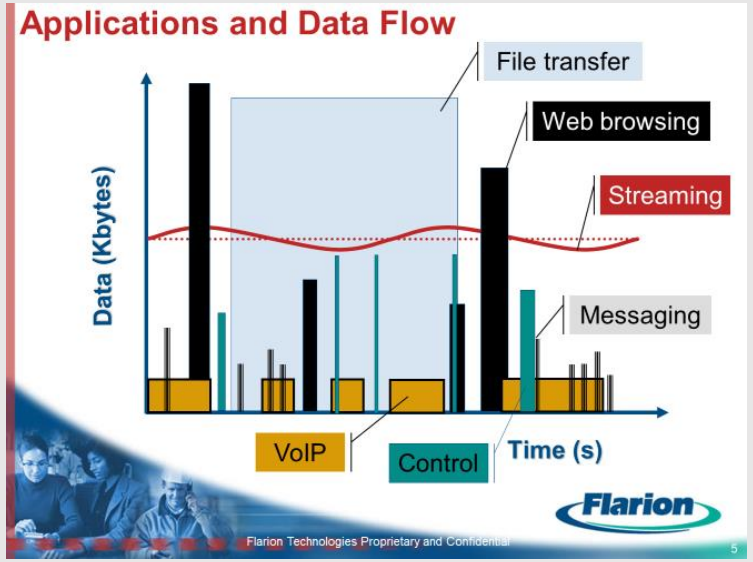
- Universal frequency reuse
- Fast power control
- Soft handoff
- Forward error correction
- Voice activity and interference averaging

CDMA: Principles of Spread-Spectrum Communication
A. Viterbi 1995

Wireless Internet ?

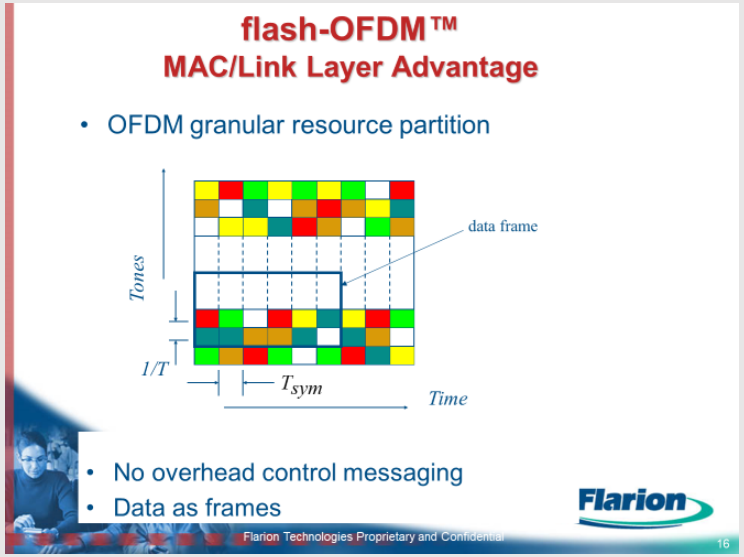
- Should the cellular network evolve to carry data or should the internet as is go mobile?
- 3GPP's answer (2G→3G) – evolve the CDMA cellular network
- Flarion's answer – take the internet mobile

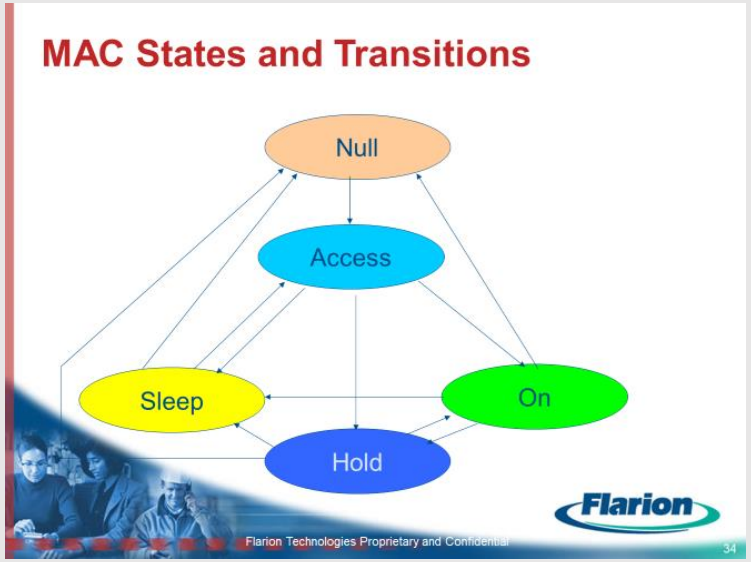




Architecture,Systems,Control

- How do you provide for rapid transitions into varying size data transmissions shared among users ?
- How do you deal with widely varying traffic demands and large signal dynamic range that is also time varying ?
- How do you make an inherently unreliable link look reliable to TCP/IP ?
- How should you hand off in an IP network, what makes sense for data traffic ?
- How do you manage resources (schedule) for good user experience ?
- How do you do all of the above simultaneously ?





What happened?

- Resistance – needed to appeal to operators
  - Infra-structure incumbants didn’t want all-IP network
  - Qualcomm didn’t want CDMA to OFDM transition
- Nextel was serious, but then bought by Sprint in 2005
- Intel pushed WiMax
- Qualcomm bought Flarion in 2006 to reset their IP position for the next generation
- World converged on the LTE (3GPP) standard (4G)

Live Network Performance Challenge
FLASH-OFDM vs. HSDPA

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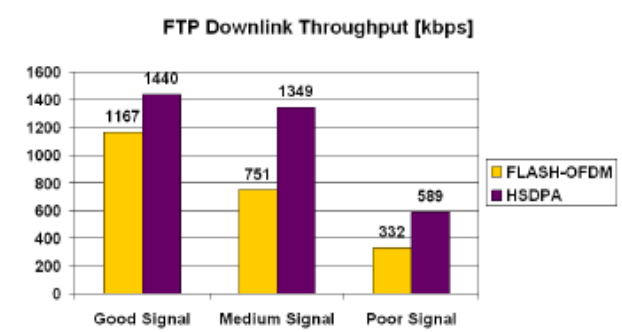


Figure 1. FTP throughput [downlink]

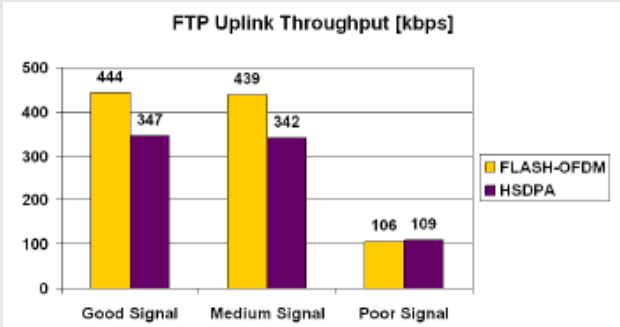


Figure 2. FTP throughput [uplink]

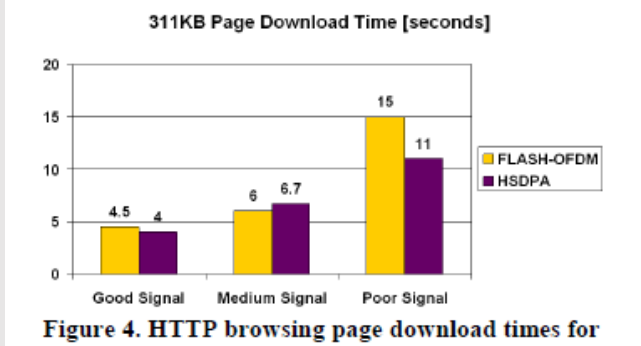


Figure 4. HTTP browsing page download times for a 311KB web page

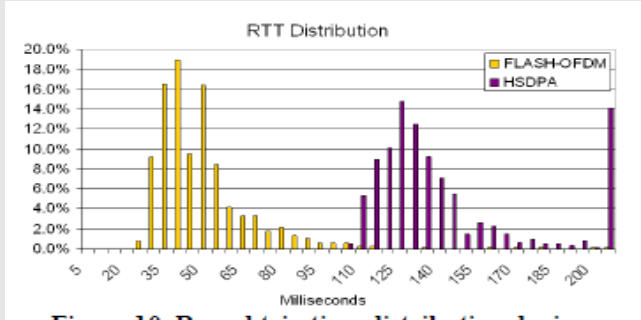
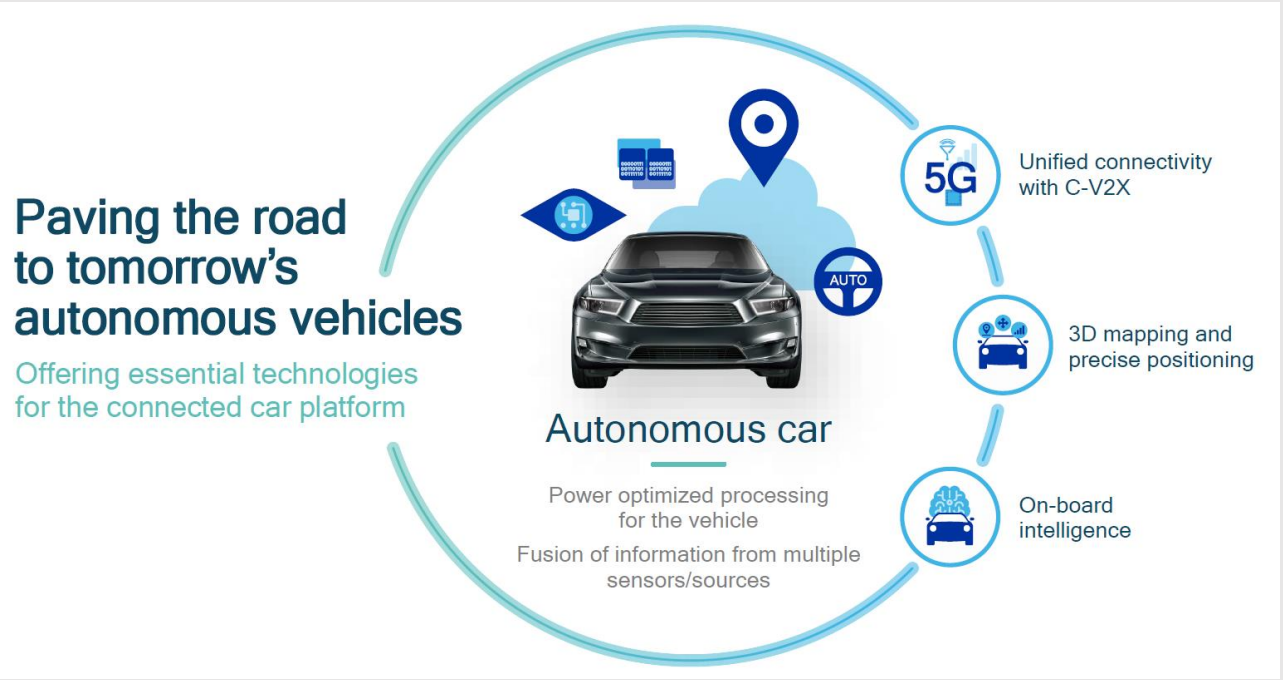


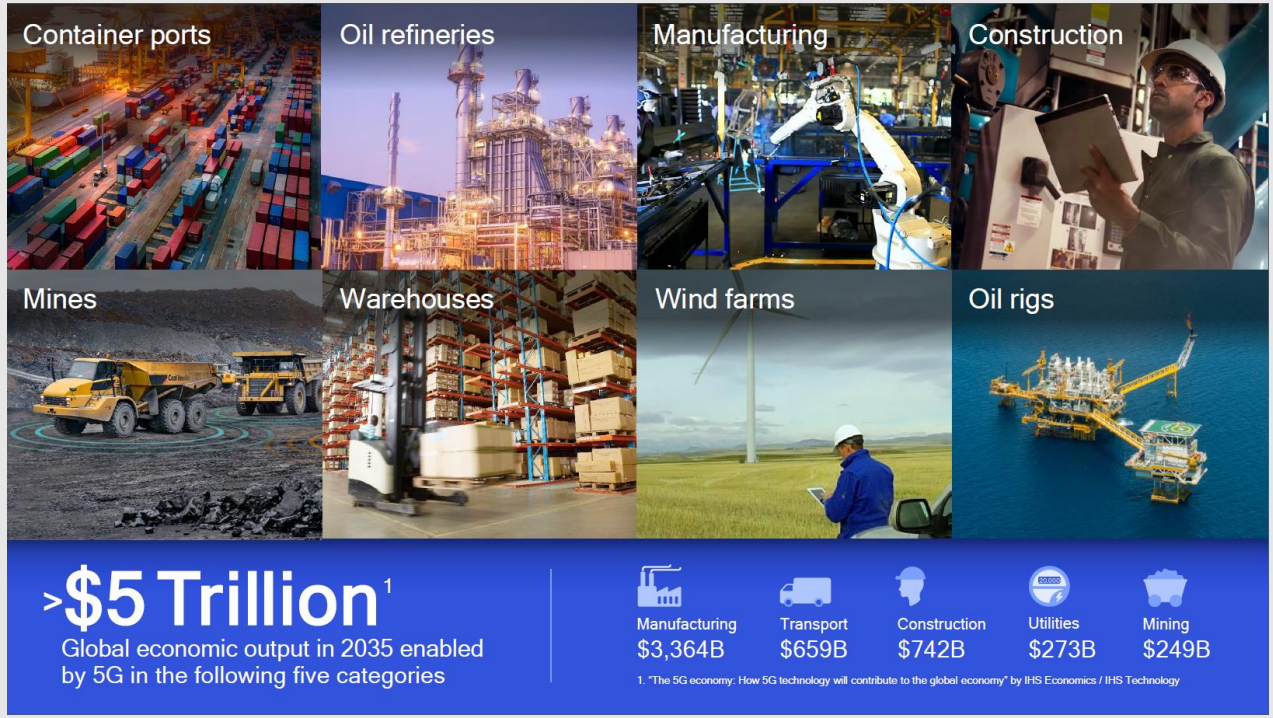
Figure 10. Round trip time distribution during mobility tests

6. Conclusions

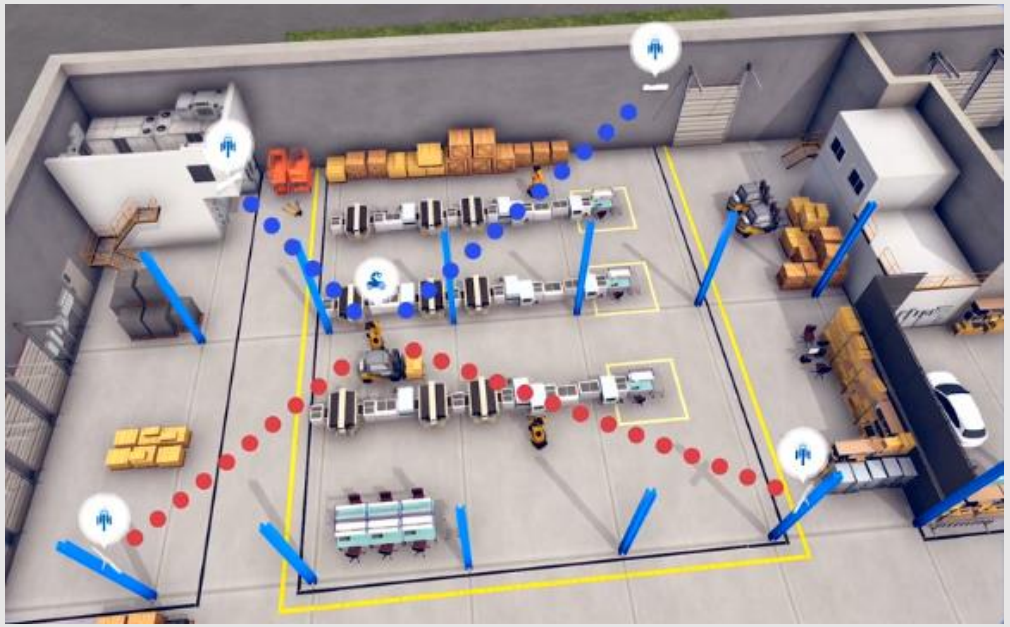
Multiple measurements were carried out to evaluate and characterize the performance of two live wireless broadband networks, FLASH-OFDM and HSDPA. The measurements show good performance in general. However, each system has its advantages and disadvantages. HSDPA is able to achieve higher throughput, and even higher with future releases. In contrast, FLASH-OFDM benefits from low and stable delay performance which results in the ability to support VoIP services with call tool quality in both static and mobile scenarios.

4G→5G: Verticals



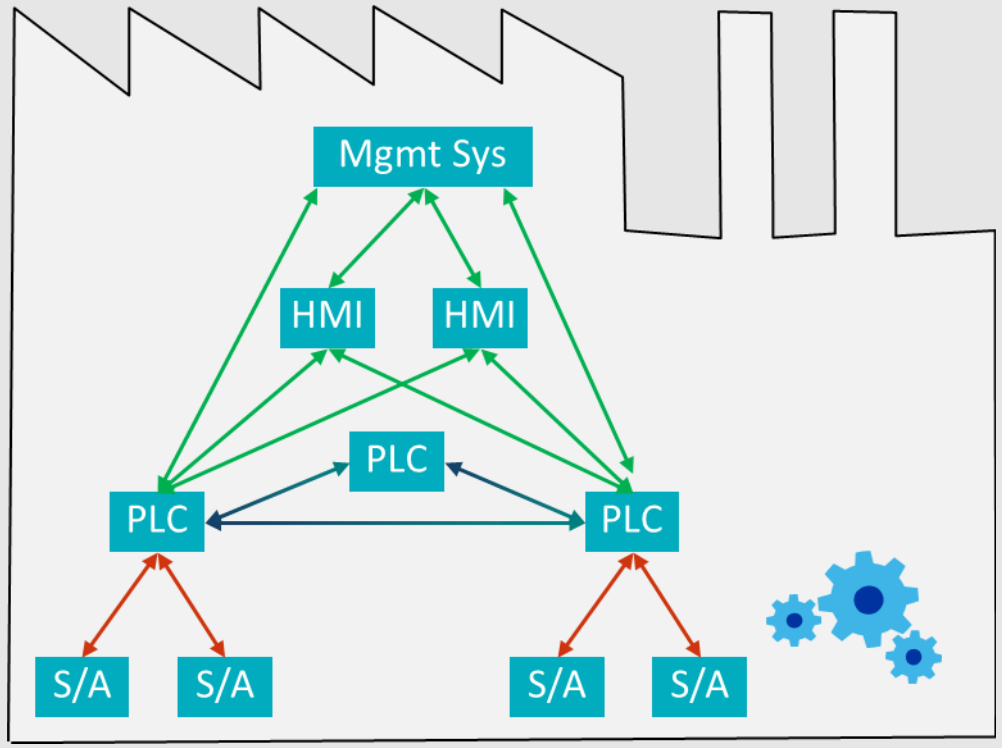


4G→5G: Industrial Internet of Things (IIoT)



- Automated/Reconfigurable factory control networks

- Scheduling/COMP for reliability
- Capacity no longer primary metric



	PLC to S/A	Inter PLC	PLC to higher entities
RTT	0.5 to 10ms	4-10ms	Similar to eMBB use cases (file download, HTML) and also extends to AR/VR
PER Target	10e-6	10e-6	
Pkt Size	40-256 bytes	1k bytes	
Range	Max 100m Typical 10-15m	Typical 100m	

Terminology and Use-Cases
Management System: Industrial PC -Controller programming -Software and Security management -Long-term KPI monitoring
Human Machine Interface (HMI): Tablet, Panels, Wearables -Machine control at the floor, e.g. Start/Stop -AR/VR scenarios in future
Programmable Logic Controller (PLC): Custom hardware -Issues series of commands (e.g. motion) and receives sensor inputs (e.g. position) in real time -Coordinates with other PLCs
Sensor/Actuator (S/A): -Rotary motor, Linear servo, Position sensor

- Traditionally, connectivity with Industrial Ethernet
- With Industry 4.0, emphasis on
  - reconfigurable factories
  - automation through robotic arms, AGVs,…
- Earlier wireless solutions based on WiFi, Bluetooth
  - Do not meet more stringent requirements