



We create the technology to connect the world

**NDIA U.S. – Finland Defense
and Security Industry Seminar
Panel on New Technologies
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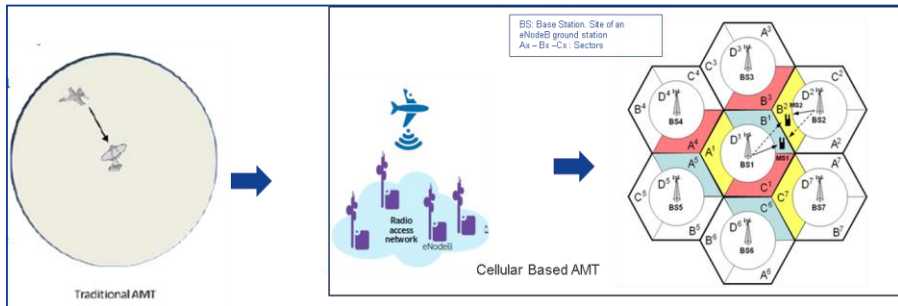
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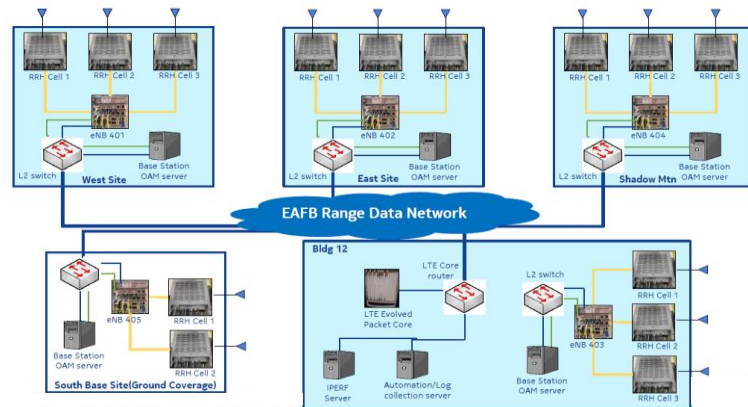


CRTM Project Highlights

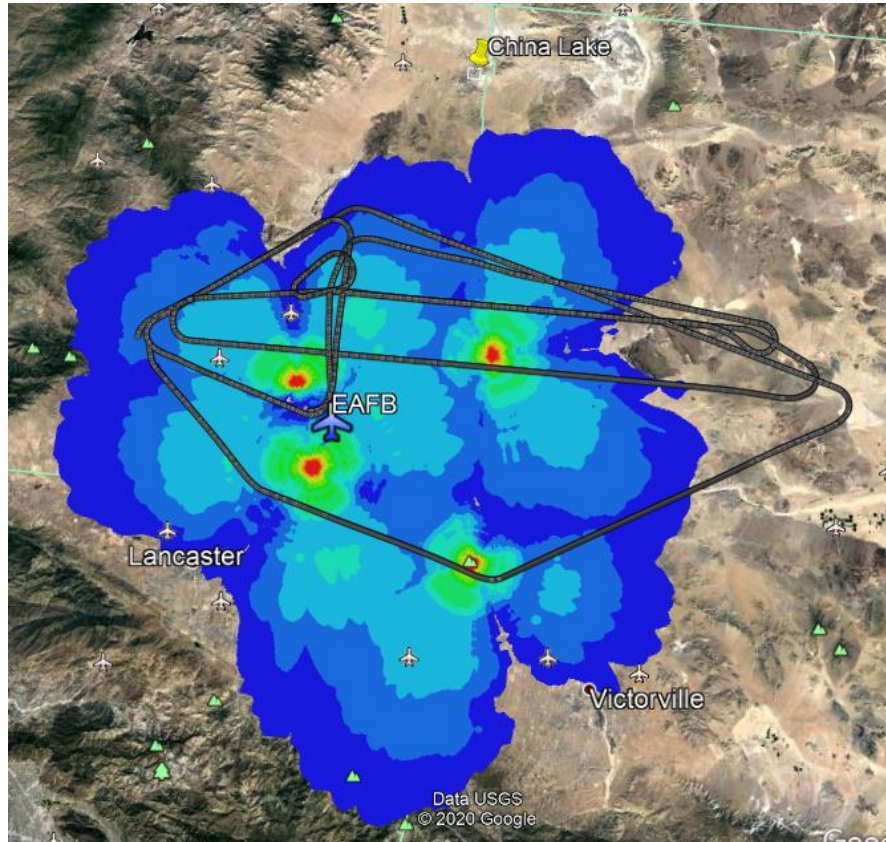
Cellular Based Range Telemetry Approach



	Traditional AMT	Cellular-based AMT
Concept of operations	<ul style="list-style-type: none"> Single frequency assignment per test article occupied over entire range Simplex data transmission 	<ul style="list-style-type: none"> Each frequency assignment is re-used in every cell and for multiple test articles Duplex data transmission
Spectral efficiency	Up to 10Mbps with enhancements	<ul style="list-style-type: none"> Average 20Mbps over range with peak capability to 40Mbps Path to higher throughput capability with 5G systems
Operational efficiency	Manual spectrum assignment with advanced scheduling	Autonomous spectrum assignment



EAFB Flight Testing



- **12.5 hours** in flight patterns
- **19** flight test “loops”
- Altitude: **7.5K Ft to 26.5K Ft MSL**
- Speed: **230-280 knots**
- Test condition variants:
 - Offered Air to Ground Throughputs: **20 and 30Mbps**
 - Offered Packet Size: **1392 and 400 Bytes**
 - **Single and Multi AT** Scenarios



CRTM Results

- **Peak Throughput >30Mbps**
- **Average Throughput 17.8Mbps**
- **Handover Success Rate 94.4%**
- **Automatic Re-establishment**
- **Doppler Correction**
- **End to End One Way Latency <50msec**
- **Multi AT exercises spectrum sharing**



Field and lab tests demonstrated efficacy of LTE-A technology for Aeronautical Mobile Telemetry

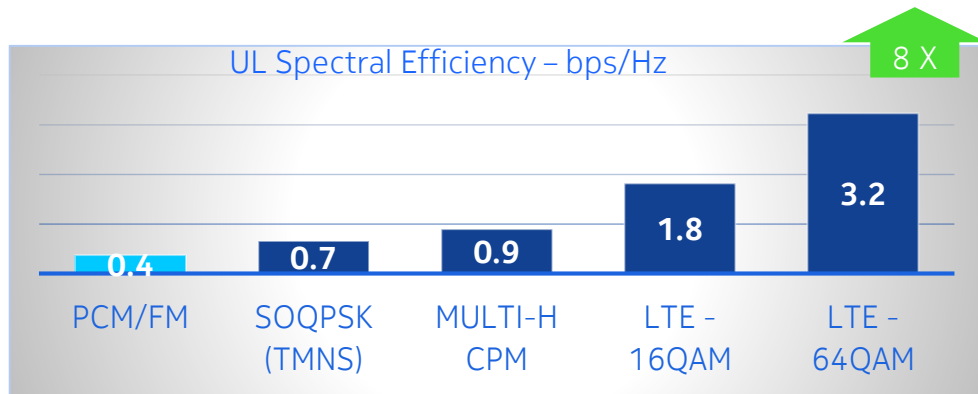
- Spectrally efficient commercial products in non congested spectrum
- Technology capable of supporting speeds of MACH2 with doppler corrections
- Seamless mobility and low latency
- Simultaneous operation of multiple test articles
- Simplified operations: always on, no frequency planning, no pre configuration, unrestricted flight patterns

5G Ready Flightline Radio Network

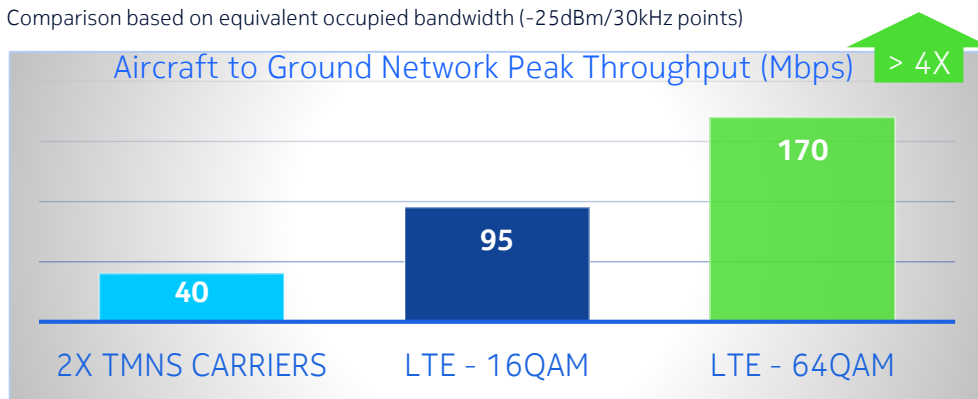


- Key Capabilities
 - Greatly increases spectrum capacity
 - Multiple users on one shared frequency
 - “Always On” therefore available “on demand”
- Technology Benefits
 - COTS 5G m-MIMO mmWave and cmWave radio and core network
 - 4G/5G Non-Standalone Core Architecture
 - Asymmetric Uplink and Downlink bandwidth
 - Spectrum sharing and enhanced security using network slicing
 - Seamless handover between FRN and SST for immediate benefit offload ground SST AMT
- Cost Advantage
 - Reduce development and sustainment costs by leveraging COTS equipment
 - Operational efficiency

Benefits of LTE for Flightline applications



Comparison based on equivalent occupied bandwidth (-25dBm/30kHz points)



Comparison based on 52MHz occupied bandwidth (-25dBm/30kHz points)

LTE offers quantum steps forward in capacity over existing telemetry link technology

- SOQPSK and Multi-h CPM doubles the spectral efficiency of PCM/FM
- LTE with OFDM and higher order modulation offers an additional 2x – 4x improvement
- Improved spectral efficiency translates into greater data throughput capability

Early FRN Demonstration

Discussion during the Flightline Radio Network project kick-off started some brainstorming on how to accomplish an early demonstration of FRN capability.

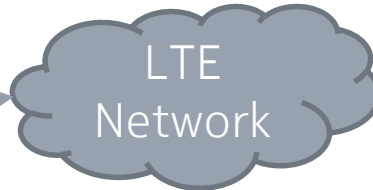
Working in conjunction with the TRMC team, a plan to deliver “live” telemetry data from an aircraft to a simulated control room over LTE was hatched ...

Early Flightline Demo is not part of either CRTM or FRN project (Nokia providing at no extra cost). Nokia wants to demonstrate how powerful LTE technology is for TRMC applications

Demonstration accomplishments:

1. Playback of recorded SST data and live video stream including end-to-end encryption totaling 31Mbps over an IP radio link
2. Simultaneous data transmission from sources representing two aircraft (31Mbps and 10Mbps) over a single LTE channel with no loss of data
3. Bi-directional data transfer: 100Mbps downlink and 41Mbps uplink
4. QoS protection of 10Mbps GBR data stream in an overloaded LTE channel
5. Sufficient range for flightline coverage

MCCR at Bldg. 1199 (416 CTF)



C-12 at Base Ops (Tarmac)



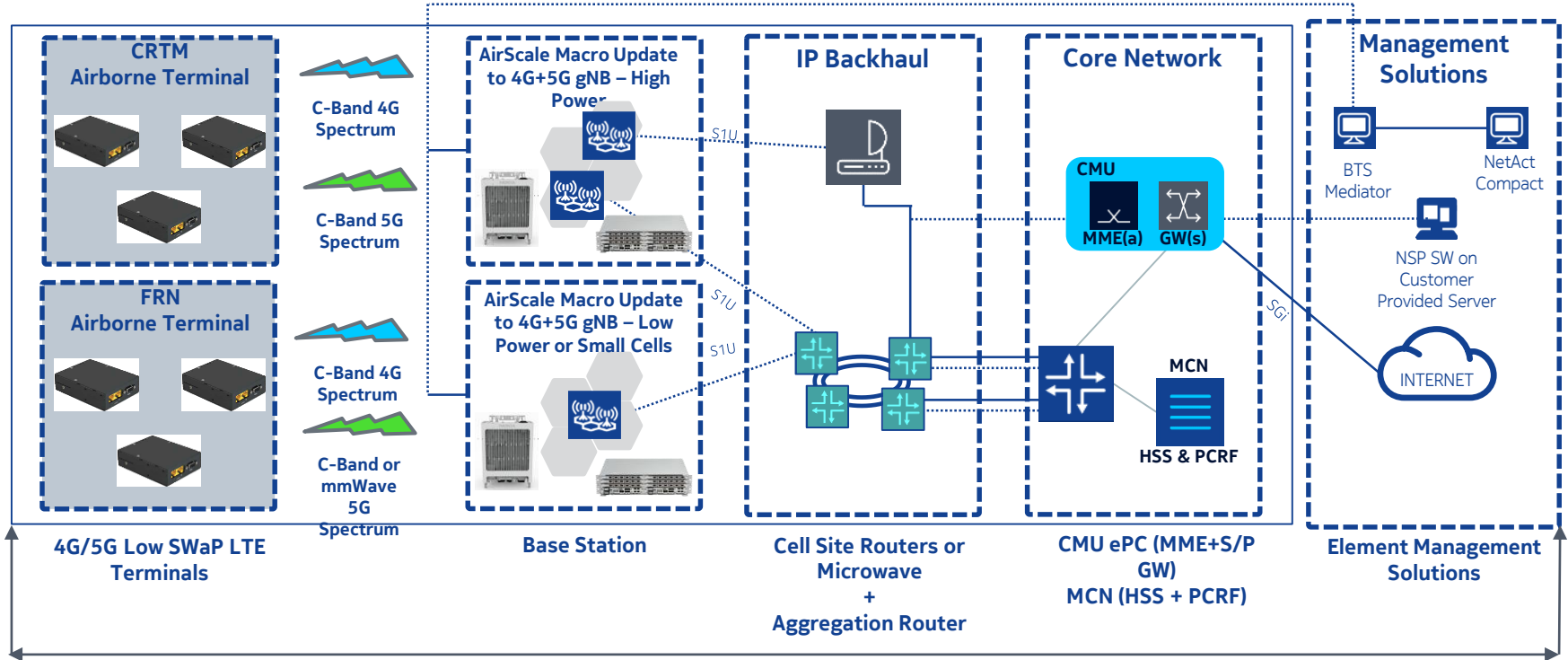
Recorded SST data converted to IP format

Commercial LTE Customer Premise Equipment (CPE) represents on-aircraft telemetry transceiver

IP data transmitted from aircraft to a commercial Band 4 RF Nokia Small Cell

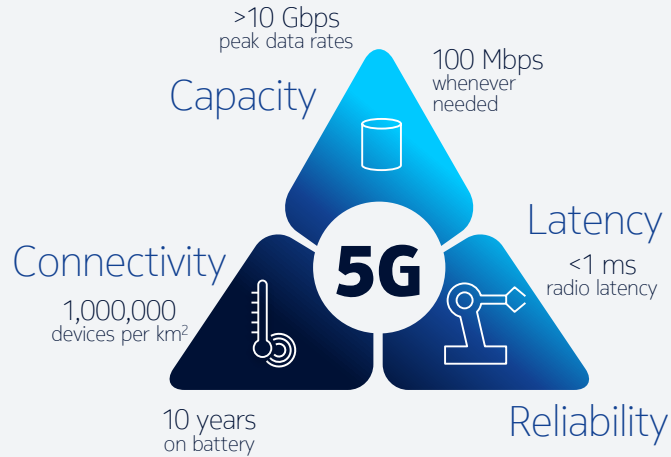
IP data converted back to SST for display in control room

Vision for 5G Ready EAFB Test Range



5G powered by a set of new technologies

Requirements



New 5G technology building blocks

New spectrum options

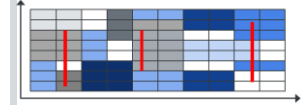


<3 GHz, 3-6 GHz, cm/mmWave

Massive MIMO & beamforming



Flexible air interface



Multi-connectivity



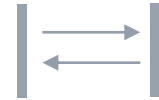
Aggregation and duplication

Cloud native & network slicing



Centralized and distributed

Connectionless communication



Efficient massive IoT

5G is a giant leap in performance

	Today	2020-25
Users	10M people	+100M 'things'
Speed	100 Mbps	100x faster
Latency	>>10 ms	10x less
NW service level	Best effort for all	Committed SLAs
Logical networks	1	Many (slices)



Smart home



Mobile gaming



Industry 4.0



Connected cars

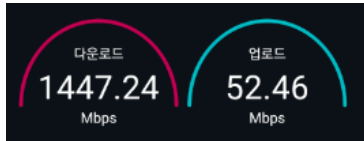


Drones



IoT wearables

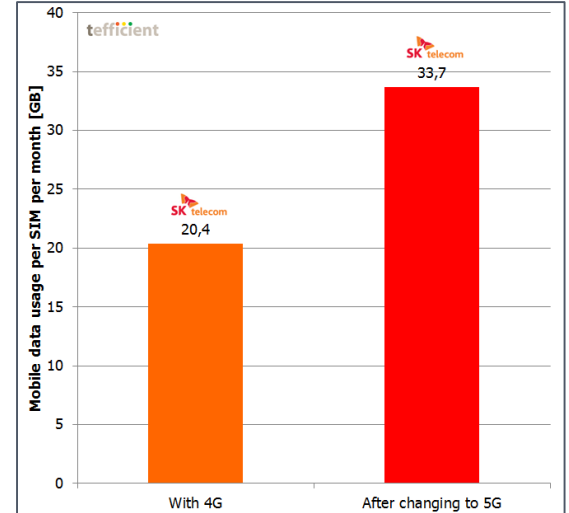
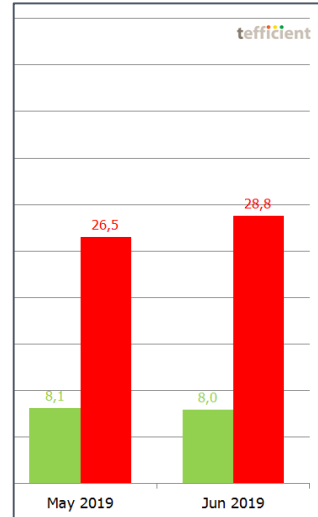
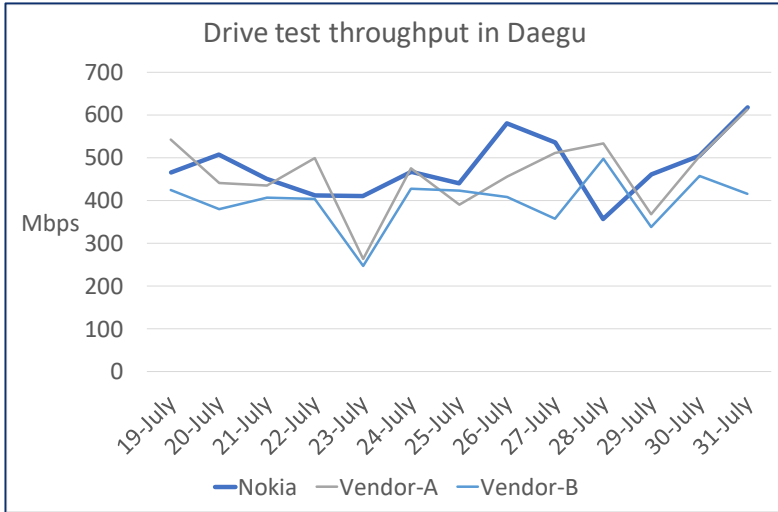
5G Throughputs and Data Usage with 3.5 GHz in Korea



Peak rate
1.45 Gbps

Average data
consumption
3.5x in 5G

Same user data
consumption +65% in 5G



Average throughput 400 – 600 Mbps in drive testing (5G + LTE)

Data usage increased from 20 GB to 34 GB after upgrading to 5G

More recent data from MWC material?

5G brings a huge variety of industry-related use cases

Each with different and demanding technical requirements ...

Discrete Automation
Cloud Robotics
Automated Seaports
Factories & warehouses
Motion Control
Remote Control
Monitoring & Sensors
Operations
Optimization
Predictive Maintenance
Fleets of Drones
Cooperative Robots



Manufacturing
Utilities
Automotive
Seaports
Mining
Agriculture
eHealth
Robotics

E2e application latency: down to 1ms
Network latency: down to <1ms
DL Tput: a few bytes to a few Mbps
UL Tput: a few bytes to 10s Mbps



Loading and Hauling
Mining Operations
Remote Control Drilling
Monitoring & Sensors
Worker Health & Safety
Automated Drilling
Remote Operations Centre
Vehicle Tracking
Environment Control
Factories & Warehouses
Drones
Process Control
Monitoring & Surveillance
Automated Exploration

What's next – the Art of Possible

Range Buildout



Low SWAP Terminal



Spectrally Efficient Smart Ranges



LTE-Advanced and 5G Connectivity

Increase test capacity and capability

- Simultaneous testing with multiple test articles
- Seamless inter-range flight test capability

Terminal for fast movers

- Ruggedized platform supporting CRTM and FRN for ground and airborne applications
- Network telemetry using bi-directional LTE radio links with SST compatibility

IoT and M2M communications

- Asset Tracking and Smart Sensors for Security, smart lighting control

High Spectral Efficiency

- Higher throughput with 5G (x20)
- 5G in unlicensed mmWave band