WIRELESS AND PROGRESS IN SOCIETY

WIRELESS – THE WAY FORWARD
Just a quick peek at Wireless

• WiFi – more than just Access points – PTMP (Point to Multi Point)
• 5G – URLLC for driverless cars medium throughput, low latency
• Microwave links / Millimeter links – instead of fiber
• Encryption and Security – the way forward
• Generation comfortable with wearables / implants
• Satellites for those on the road
• Reduction in power levels – radiation safety
• Conclusion
Beyond WiFi 6 – In Unlicensed Bands

- 2.4 GHz band (83 MHz bandwidth) is widely used by all WiFi devices (including cell phones); allows max EIRP of 4W – it is not a good option.
- But the UNII bands in 5 GHz range with lower power are very useful.

<table>
<thead>
<tr>
<th>Max Power (EIRP)</th>
<th>50mw (200mW)</th>
<th>250mW (1W)</th>
<th>250mW (1W)</th>
<th>200mW(1W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation(BW)</td>
<td>U-NII – 1(100MHz)</td>
<td>U-NII-2A(100MHz)</td>
<td>U-NII-2C (255MHz)</td>
<td>UNII-3(125MHz)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>5150 MHz</th>
<th>5250 MHz</th>
<th>5250 MHz</th>
<th>5350 MHz</th>
<th>5490 MHz</th>
</tr>
</thead>
</table>

- Weather Radar

Unlicensed National Information Infrastructure (UNII) bands 1, 2A, 3 can be used.
PETRO CHEMICAL FACILITY

Chemical facility: Assume following safety guidelines for monitoring:

1. All tanks monitored by sensors for fluid level, temperature and venting:
   Data rate up to 200Kbps.
2. All open tanks – monitored by camera, view construction crew, send text messages. Camera + WiFi (802.11) enabled devices from construction workers: 2.5Mbps. Text: 10Kbps
3. All processing plant area – periodic sensor reports on production line sensors: Data rate: 100Kbps
4. Transport /shipping area: Hourly Scheduling and dispatch report by text. Data rate: 50Kbps
5. Cameras observing transport movement throughout the facility: 15 Mbps
6. **ALL ANTENNAS ARE DIRECTIONAL** – High gain Panels of 30, 60, 120 degrees

In Point to Multipoint (PTMP) Wireless – Base Station (BS) initiates conversation TDMA – Subscriber Units respond to commands
1. Storage areas – BS1 through BS6 marked in **red**
2. Process plant area – BS1 through BS4 marked in **Blue**
3. Transport and shipping area – BS1 and BS2 marked in **Purple**

Each of them supported by a Layer-2+ security protocol provided by the vendor

Each backhaul has 128bit or 256bit encryption

A. Trans Bridge – in 5GHz band with throughput up to 500Mbps **RED dotted**

B. 60 GHz millimetric wave short link (<1km), throughput up to 1Gbps **GREEN dotted**

C. 80 GHz millimetric wave long links (<5 km), throughput up to 10 Gbps **BLUE dotted**
5G – URLLC and Multiple beams

<table>
<thead>
<tr>
<th>Enhanced Mobile Broadband (eMBB)</th>
<th>Ultra-Reliable and Low Latency Communication (URLLC)</th>
<th>massive Machine-Type Communication (mMTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All data, all the time – two billion people on social media</td>
<td>Ultra-high reliability, Ultra responsive</td>
<td>30 billion connected “things”, with Low cost, Low energy</td>
</tr>
<tr>
<td>500 kmph mobility (high speed rail), 10-20 Gbps peak data rates</td>
<td>&lt; 1mS air link latency, 5mS end-to-end latency, 99.9999% reliable, 50 Kbps – 10 Mbps</td>
<td>105-106 devices / Sq.km, with 1-100 kbps / device, ten year battery life</td>
</tr>
</tbody>
</table>

- 700 or 800 MHz full wavelength $\lambda$ would be 0.428 meter and half wave $\lambda/2$ will be 21.4 Cm.

- How many antennas fit in your smartphone?

- Base station can transmit many beams with dual polarization

- eNodeB (Base Station)

- User Equipment

- 8 X 2 beamforming system creates Orthogonally polarized beams

- But the question is: How many beams can your smart phone actually receive?

- NFC / RFID chip at 13.56MHz

- Wearable camera and its recorder
5G – URLLC and driverless vehicles

- Reliability is VERY HIGH
- Throughput is MEDIUM
- But latency is VERY LOW

SAE (Society of Auto Engineers)

Ultra-Reliable and Low Latency Communication (URLLC) 5G standard
Ultra-high reliability, Ultra responsive
< 1ms air link latency, 5ms end-to-end latency, 99.9999% reliable, 50 Kbps – 10 Mbps
ADVANTAGES
Single national network – FIRSTNET in USA
• POLICE, FIRE AND EMS communicate across states
• Commercial smart phones – with PTT features
• 4G LTE and all smart phone features available
• In addition – uses public safety 700MHz bands

LIMITATIONS
• Operated by cellular carrier (AT&T and Verizon in USA)
• SIM card and monthly charges apply

Both P25 and TETRA standards approached 3GPP to merge into 4G
After multiple releases, now Rel 17 (2021) fully supports public safety
Millimeter wave links and Gbps

Unlicensed 60 GHz band

- < 1 ms latency
- Short hops from 1 Gbps to 10B Gbps (up to 5 km)
- Latency < 200 μs

The remote tower (Reliability and monitoring)

60 GHz – 1 Gbps, and Low latency (< 200 μs)

Links distances up to 5 km in dry areas

Stable back haul links up to 10 Gbps throughput, with 99.999% reliability and low latency (< 200 μs)

The unit needs only one single mode fiber to carry traffic of over 1Gbps from antenna to Reliability and monitoring.

All microwave radios have built in IP ports with VLAN capability. PoE is possible in most cases. AES 256 encryption is standard for all microwave links.

70/80/90 GHz band was allocated by FCC as licensed bands for point-to-point links as licensed bands for point-to-point links

10 Gbps
Encryption and Security

Hierarchical keys and method of key generation between entities in LTE

KEY IS NOT SENT OVER THE AIR

INT – Integrity
ENC – Encryption

IT IS SAFER TO DO YOUR FINANCIAL TRANSACTION OVER CELLULAR CONNECTION – Banks have begun to recognize this fact

USIM – Universal Subscriber Identity Module
ME – Mobile Equipment
UE – User Equipment

AKA – Authentication and Key Agreement
CK – Cypher Key
IK – Integrity Key
MME – Mobility Mgmt. Entity
ASME – Access Security Mgmt. Identity
AuC – Authentication Center
AS – Access Stratum
NAS – Non-Access Stratum
HSS – Home Subscriber Server
RRC – Radio Resource Control
Entire Generation comfortable with wearables

Breast pump allows multi-tasking and ability to use in workplace or public area

UHF ultra light microphone

Wearable tracker
Kits for Soccer

GPS, 6-axis Gyro, Accelerometer

Video Sport Camera +Digital Camcorder

1 Week Battery

Precise sensor worn around your finger where pulse is stronger. Captures body signals like temperature, heart rate, HRV, calorie burn

Popular wireless technologies for wearables

1. NFC – Near Field Comm.
2. BLE – Bluetooth Low Energy
3. Bluetooth Classic
4. WiFi – IEEE 802.11
5. Cellular - LTE

FUTURE – PRINTED WEARABLES
Satellites for those on the move

AIRCRAFT COMMUNICATION (1530-1559 MHz)

LEO

PERIGEE

MEO

GPS

HEO

APOGEE

TUNDRA

POLAR

REMOTE SENSING (400-13000 nm)

SHIPPING / NAVIGATION BANDS (2 – 40 GHz)

GPS 1164-1610 MHz

APEX

GPS 1164-1610 MHz

2.3 GHz

GPS 1164-1610 MHz
Reduction in power levels - safety

<table>
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<tr>
<th>Occupational / Controlled Exposure limits</th>
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<tr>
<td>Whole body</td>
</tr>
<tr>
<td>0.4</td>
</tr>
</tbody>
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<table>
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<tr>
<th>General population/ uncontrolled Exposure limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body</td>
</tr>
<tr>
<td>0.08</td>
</tr>
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* TV broadcast tower 200kW
* Early Radio broadcast towers 500kW
* Cell tower – 75 watt (max)

* WEARABLES – 0.01W typical
* Blue tooth Low energy 0.01W to 1/5 W (max)
* Leakage from MW oven door – 5mW
* Blue tooth classic 1/5 watt (max)

Human head model and SAR measurements

SAR – Specific Absorption Rate

* Cell phone – 1/5 watt (max)
* WiFi AP – 1/5 watt (max)
Conclusion

- Wireless has become – universal access to the Internet
- Use cellular, or WiFi? depends on where you are – WiFi at destination
- PTMP offers simpler solutions to process chemical industry / city blocks etc.
- Expect URLLC and cellular to take over the driverless car market
- Backhaul is not exclusively wired / fiber, over 50% of backhaul is MW
- Cellular network is more secure than wired IP network – 5G will enhance it further
- Smart phone is crowded with antennas – Qualcomm works with Cell phone vendors to place the entire RF network and antenna in handsets (antenna can’t be where you hold the phone)
- Society is comfortable with wearables – convenient apps and flexibility
- Satellite communication is growing too fast – GEO is crowded with 550 satellites
- RF power levels continue to drop – only broadcast towers still use high power
- RF power is non-ionizing radiation – no cell tower is at power levels allowed by the FCC – typically it operates at 1/10 power levels allowed by regulators