It’s a Wireless World we live in

How Advances in Wireless Technology Will impact You

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Agenda

- What is 5G?
- What will 5G deliver?
- What is 5G not?
- Where will 5G revenue come from?
- What are the timeframes for deployment?
- How does 5G fixed wireless work?
- mmWave – what are the issues? Answers?
- What is the impact on property and equipment valuations?
- Questions
iGR’s Products and Services

- Wireless and Mobile Landscape
- 5G
- End-User Quantitative and Qualitative Studies
- Small Cells, DAS & HetNet Architectures
- IoT
- Custom Research Services
- Content Marketing Products and Media Support
- Sponsored Research

Source: iGillottResearch, Inc, 2018
What is 5G?
What is 5G?

- Simply, next generation of wireless technology
  - Continues 2G, 3G, 4G lineage
- Defined by 3GPP as Release 15
  - LTE started as Rel. 8
  - Simply a ‘line in the sand’
- 4G LTE was a fork-lift upgrade to the 3G networks
  - Little commonality
- But 5G is a continuing evolution of 4G LTE
  - A strong LTE base means a strong start to 5G
  - But with a new architecture
What will 5G deliver?
What will 5G deliver?

5G Phase 1 (Rel. 15) NSA
Enhanced Mobile Broadband with High Bandwidth and Throughput

5G Phase 2 (Rel. 16/17) SA Enhanced EPC
Along the way :)
Low Latency and Ultra Reliable Communications

5G
Massive IoT and Machine Type Communications
Smart cities
Asset tracking
Remote patient monitoring

Gbps
HD Video
Fixed Wireless

AR VR
Remote Surgery
Industrial automation

Source: iGillott Research, Inc, 2018
What is 5G not?
5G is not...

- A totally new network from LTE
  - Uses the same waveform in the air interface
  - Initially uses the same EPC
- Designated for a specific spectrum band
  - There is no ‘5G band’
  - mmWave is not just for 5G; 5G is not ‘everything above 6 GHz’
- Changing the rules of physics 😊
- Cheap or easy to deploy
What are the timeframes for deployment?
5G Deployment

- **Phase 1**
  - Very late 2018, into 2019
  - 5G New Radio with LTE EPC
    - Need LTE to establish a 5G connection
  - Rel. 15 NR standard was finalized late 2017
  - 5G NR devices early 2019
  - Race among MNOs to launch 5G first
  - High bandwidth only

- **Phase 2**
  - New low-latency EPC
  - Move processing closer to the edge
  - High bandwidth and low latency
Forecasted U.S. Mobile Connections, 2017–2027 (Millions)

Very few
U.S. Mobile Data Traffic by Generation, 2017–2027 (%)

LTE still majority of traffic in 8 years!

Source: iGillottResearch, Inc, 2018
So how much will 5G cost?

- Spending on *building* 5G between 2017 – 2027
  - Includes *incremental* operating cost 2017 – 2027
  - No additional cost for LTE build/enhancement
  - Includes 5G radio, core and backhaul
  - Does not include edge compute spending for enterprise
  - No spectrum cost
- **U.S.** $64.651 Billion
- Europe $100.214 Billion
- Asia Pacific $197.223 Billion
Prepping for 5G

- Virtualization and SDN
  - Core ongoing
  - Support functions ongoing
  - Edge next
  - RAN starting
- Densification
  - Already on-going
  - Inability to deploy small cells in significant numbers could impact 5G
- In-building coverage
  - Higher bands used in-doors
- D-RAN and C-RAN
  - Part of the virtualization push
  - Aids densification
- eCPRI
  - Supports C-RAN, densification, etc
U.S. Total Mobile Network Infrastructure Build Spending, 2017–2027 ($M)

The last good year for capex
Put that in perspective for me 😊

U.S.
~330 million subs
+$1.99 per sub/mth

Europe
~800 million subs
+$1.11 per sub/mth

Asia Pacific
~3.2 billion subs
+$0.63 per sub/mth

Source: iGillott Research, Inc, 2018
How Latency Adds Up
Reduced latency by co-locating apps/content server with the base station
Reduced latency with traffic steering and prioritization
Where will 5G revenue come from?
Mobile Broadband

Will provide *some* revenue – more than likely similar to today’s ARPU

Problem is ARPU currently declining

Will continued competition let ARPU increase?

Obviously, ~300 million potential U.S. consumer customers

Home Broadband

Fixed Wireless Access

~110 million U.S. homes
~7 million U.S. small businesses

Why give up traditional broadband connection?

Serious money but need to build infrastructure

Likely minority of homes/businesses adopt
Categorizing 5G Revenue Sources

Entertainment

The Netflix model? Another model?

Good content not limited to broadcast/cable TV

AT&T – DirecTV current model – Time Warner?

T-Mobile planning TV service for 2018

Advertising

Specifically video and entertainment

Emulates the Internet model?

How do you overcome ad-blockers?

Insert in the entertainment stream?

Consumer willing to get ads?
**Categorizing 5G Revenue Sources**

**IoT**
- Can be provided with LTE, LP LTE, LPWAN, etc
- Does not *need* 5G
- Low latency IoT needs 5G
- Hundreds of millions of potential connections in multiple market segments
- Some revenues likely available but enough to move the needle?

**Network Slicing**
- Carve out network resources for specific entities/apps
- Corporation supports employees
- Brand/app/service provides bandwidth
- Revenue potential unproven and needs business model development
- Net neutrality?
U.S. Total Annual 5G Revenue ($M), 2017–2027

Source: iGillott Research, Inc, 2018
How does 5G fixed wireless work?
Where are we at with Fixed Wireless Access?

- Much focus for 5G
- Trials conducted in late 2017
- Focus on mmWave
  - Question of whether just build FWA network or support mobility as well
  - Costs increase if include mobility
- Also discussion of using 3.5 GHz CBRS for FWA
  - Waiting on final rules from FCC
  - Appeal is potentially low cost of licenses AND relatively large amount of spectrum
  - Two power levels supported
Who is using Fixed Wireless Access?

- **Windstream**
  - Multiple markets

- **Comcast**
  - Hoping to test mobile and fixed wireless services using the 3.5 GHz CBRS band
  - Conduct outdoor and indoor fixed and mobile testing in a small targeted portion of the Philadelphia, Pennsylvania, market

- **Open Broadband**
  - Operates fixed wireless services in four communities in North Carolina, and is working to expand into South Carolina, Virginia and elsewhere

- **Rise**
  - Around 200,000 customers in rural locations in a number of states across the country

- **Redzone Wireless**
  - Maine-based; plans to incorporate millimeter wave spectrum in its 5GX network to begin offering gigabit broadband speeds to residential and commercial customers in selected areas of Portland in the first quarter of 2018

- **Common Networks and Starry** both use varieties of the 802.11 Wi-Fi standard for their respective fixed wireless services

- **Verizon**
  - Samsung Electronics America will provide commercial 5G Fixed Wireless Access network solutions to Verizon for the debut in Sacramento, Calif., including home routers, Radio Access Units and radio frequency planning services
  - Verizon has said its addressable market for its residential fixed wireless broadband service maxes out at 30 million households, or just 24% of the overall U.S. market

- **AT&T**
  - Company’s 5G tests in Austin found that AT&T could bounce 28 GHz signals around obstructing foliage in order to reach a receiver almost a mile away. But indoor receivers were stymied by reflective window coating, forcing the carrier to test an indoor system through more traditional dual-pane glass
  - FCC announced a settlement with AT&T’s FiberTower that involves the company returning hundreds of millimeter wave spectrum licenses to the agency
  - AT&T will only get around 479 of FiberTower’s 39 GHz spectrum licenses and none of the company’s 24 GHz licenses

- **Etc.**
Verizon/Samsung/Arquiva
Windstream/CBNL
mmWave – what are the issues? Answers?
How good is the mmWave spectrum?

- **The Good**
  - Lots of it
  - Wide channels
  - Capacity is good
  - Available from multiple sources
  - Multiple bands to fit different needs
    - 24 GHz, 28 GHz, 29 GHz, 31 GHz, up to 70 – 80 GHz

- **The Bad**
  - Propagation is limited
    - The higher the frequency, the shorter the signal goes!
    - Signal disperses in the air
    - Worse in humid/wet conditions
  - Need many cells to cover a given area
  - Trees, buildings, water block signals
  - Service experience will vary depending on weather and conditions
    - Operators like predictability…
  - Need advanced diverse antennas in devices
    - Adds to cost

One solution: hybrid

- mmWave from tower to a neighbourhood hub
- Then Wi-Fi from the hub to neighbouring homes
- Provides some mobility in a given area
- Allows for optimum mmWave deployment
Bands Proposed by FCC for Mobile Use, 2016

Source: FCC, 2016
Measuring Effect of Hand Blocking and Role of Diversity

Source: the Promise of 5G mmWave – How Do We Make it Mobile?; Qualcomm, 2016
What about mmWave Mobility?

- Short wavelengths make mmWave connections highly vulnerable to attenuation
  - Complete blockage from foliage and other objects – including the end user’s hand/body
  - Likelihood of disruption increases dramatically when the device is moving through the network
  - But how fast can it move before it becomes an issue?
- Beamforming helps mitigate signal interruption and attenuation
  - But compute power necessary generates heat and draws a lot of battery power
- Both negatives when the mobile device is small, such as a smartphone or tablet
  - These techniques also are new
  - Price premium because they have not started down the cost curve
- Drawbacks limit the addressable market
  - Especially for IoT – notoriously price-sensitive and often has stringent power requirements
## Test Results of Mobility at 24 GHz

<table>
<thead>
<tr>
<th>Mode (Normal Line of Sight connectivity)</th>
<th>Maximum Functionality / Average Link Speed (Mbps)</th>
<th>Percentage related to Optimal Stationary Fixed Conditions (which is: 11 Mbps avg. download; 21 Mbps avg. upload)</th>
<th>Extrapolation of Results to 180 Mbps full duplex System</th>
<th>Baseline for Extrapolation Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote unit traveling at 6 MPH over 0.2 miles in line-of-sight conditions. State highway 28: Georgia Avenue, Silver Spring, Maryland.</td>
<td>5.3 Mbps avg. download; 14 Mbps avg. upload.</td>
<td>Download: 48.18%; Upload: 66.67%</td>
<td>103.365 Mbps full duplex</td>
<td>Download: 48.18%; Upload: 66.67%; Combined for average 57.425%</td>
</tr>
<tr>
<td>Remote unit traveling 1-2 Mph backwards and forward 215 feet from base station, across railroad tracks and state highway.</td>
<td>9.5 Mbps avg. download; 20 Mbps avg. upload.</td>
<td>Download: 86.36%; Upload: 95.24%</td>
<td>163.44 Mbps full duplex</td>
<td>Download: 86.36%; Upload: 95.24%; Combined for average 90.8%</td>
</tr>
</tbody>
</table>

### iGR’s Opinion:

Data speed loss with slow speed movement is significant. Higher speeds will be far more problematic. mmWave therefore likely to be a fixed and nomadic in highly dense areas NOT full mobile metro solution.

Source: FiberTower, 2016
Multi-User MIMO and Massive MIMO

- MU-MIMO needed for successful mmWave deployment
- Multiple antennas to increase power
- Beamforming
  - Z-axis for taller buildings
- Massive MIMO antennas are bigger
  - But not necessarily massive
  - Need suitable location
Where FWA will make sense

- Good geography and topography ✔️
- Limited foliage, trees, etc ✔️
- Population density ✔️
- Socio-economic for high penetration of broadband use ✔️
- Limited or no fiber availability ✔️
- Limited broadband competitive choices ✔️
- Limited broadband speeds available ✔️
- Poor perception of incumbent ISP ✔️
Fiber FWA can make sense depending on configuration

Legacy copper

FWA Sweet Spot

% adoption in given coverage area

Dense

Population Density

Sparce
What this all means

- 5G not needed for everything
  - 5G IoT connections are those that need low latency and/or massive bandwidth
- Low latency is the key
  - Edge compute to get the latency down
- Only certain apps need low latency
  - Robots, control, etc
  - Need to understand application
    - Enterprise, enterprise, enterprise
- Network slicing in cases where performance must be guaranteed
  - Remote surgery
- Edge computing deployments needed for 5G to be successful
  - Fundamental architecture change

- But edge computing does not need to wait for 5G
  - Can be effectively deployed with LTE, LTE-U, Wi-Fi, etc
- Edge computing can be part of the mobile network architecture but does not have to be
  - Can be deployed by an enterprise...
  - Can be enabled by an MVNO...
  - Or as part of a private network

The mobile world gets interesting when you:
- Start thinking of the benefits
- Start imagining where to put a micro data center
- Work out who in the IT community you could work with
Impact for valuations

1. New network equipment across the board
   - Antennas, radios
   - Packet core
   - Edge computing

2. Equipment in new locations
   - Edge computing at macro sites
   - Edge computing and RAN in the basement of commercial buildings
   - FWA equipment in homes

3. Operators will deploy 5G
   - Spending billions

4. But so will third parties
   - Especially for in-building solutions
   - MNOs will lease access to third party networks

5. Increased use of the off-the-shelf hardware
   - Rapidly moving away from dedicated hardware
   - This starting to include the RAN
     - Finally...

6. Increased virtualization
   - Increased value from software
   - Especially for edge computing solutions
   - Improved packet core all virtualized

7. Massive increase in use of fiber
   - Need fiber for low latency
   - Increased bandwidth = increased backhaul
   - Everything connected with fiber
Questions?