Consumer expectations driving largest 5G Market Share

- High-Speed Infrastructure Growth
- Strong data network
- 5G-enabled Smartphones
- With minimal delay

North America expected to hold the largest share of the 5G infrastructure market in 2020

Global 5G Infrastructure Market worth 33.72 Billion USD by 2026

5G Connections is expected to exceed 2.7B by 2025

*From MARKETsandMARKETS and CCS
DATA GROWTH
No signs of slowing

360,000%

Data traffic growth on AT&T’s mobile network since 2007

HEALTHCARE
MANUFACTURING
FINANCIAL SERVICES
PUBLIC SAFETY
TRANSPORTATION
INDUSTRY EVOLUTION

3G → 4G/LTE
Real throughput for customer in production/field 10-15 Mbps
Higher throughput up to 150 Mbps with LTE-A
Latency: 80 ms

5G
Higher throughput up to 10 – 20 Gbps
Latency: 20 ms

HEALTHCARE  MANUFACTURING  FINANCIAL SERVICES  PUBLIC SAFETY  TRANSPORTATION

© 2018 AT&T Intellectual Property. All Rights Reserved. AT&T, the Globe logo, Mobilizing Your World and DirecTV are registered trademarks and service marks of AT&T Intellectual Property and/or AT&T affiliated companies. All other marks are the property of their respective owners.
5G INCLUDES KEY CAPABILITIES ESSENTIAL FOR NEXT GENERATION MOBILE EXPERIENCES

**Speed & Efficiency**
- Will support 1 Gbps+ speeds
- Fiber-enabled backhaul
- Increases spectral efficiency with use of multiple antennas

**Massive IoT**
- Will support low-cost IoT modules
- Enables billions of connected devices world-wide

**Low latency**
- Real-time network
- Expanded coverage
- Supports immersive multimedia experiences
5G promise unlocks use cases that are dependent on speed, coverage & low latency

<table>
<thead>
<tr>
<th></th>
<th>Autonomous vehicles</th>
<th>Robotics</th>
<th>AR/VR</th>
<th>eSports</th>
<th>Drones</th>
<th>Far-field communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Coverage</td>
<td>✓</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Latency</td>
<td>✓ &lt;5 ms</td>
<td>✓ &lt;5 ms</td>
<td>✓ 10-15 ms</td>
<td>✓ 10-15 ms</td>
<td>✓ &lt;15 ms</td>
<td>✓ &lt;20 ms</td>
</tr>
<tr>
<td>Examples</td>
<td>In-car video</td>
<td>Manufacturing</td>
<td>Training</td>
<td>Augmented sports</td>
<td>Package delivery</td>
<td>Connected responder</td>
</tr>
</tbody>
</table>
5G & SDN: Worlds Colliding
THE FUTURE IS SOFTWARE-DRIVEN RADIO
Emerging Technologies are demanding lower latency and accelerated processing at the edge

<table>
<thead>
<tr>
<th>Emerging Technology Enablers</th>
<th>On-demand NFV</th>
<th>Hardware Acceleration</th>
<th>A.I.</th>
<th>Microservices</th>
</tr>
</thead>
</table>

**NFV Edge Infrastructure**
- Wireless (vRAN, vEPC..)
- Wireline (PON, ..)
- uCPE (SD-WAN..)
- IP Enterprise services

**Autonomous Devices**
- Drones
- Autonomous vehicles
- Industry Robots
- Medical

**Immersive Experiences**
- Virtual Reality
- Augmented Reality
- 360 Video
- Wearable Cognitive Assistance

**IOT & Analytics**
- Industrial Sensors
- Home Devices
- Retail
- Healthcare

**Emerging Technology Enablers**
- On-demand NFV
- Hardware Acceleration
- A.I.
- Microservices
Operator’s owned Network Edge are optimal zone for edge placement

- **Millions**
  - Customer Devices
    - Mobile
    - AR/VR
    - Drones
    - Autonomous Vehicles
  - Customer Premises
    - Home
    - Smart Cities
    - Small Enterprises
    - Stadiums
    - Enterprises
    - Public buildings

- **Thousands**
  - Access Methods
    - 5G
    - LTE
    - Wifi
    - Wireline
  - Telco Network Edge
    - Tower
    - Central Offices
    - Other Telco real estates (wire centers...)

- **Tens**
  - Backbone
    - Central Cloud
    - Public Clouds
  - Non-accelerated processing ~5-50 ms

- **Device** ~2 ms
- **Last mile network** <5 ms
- **Access** 1-3 ms
- **Edge computing** ~5-20 ms
- **Backbone** ~2-100

**Edge Placement**

- **Burst Capacity**
- **Optimal Edge Zone**
- Not Optimal

**Estimates**
AT&T’S 5G ENABLEMENT
The Evolution to 5G

Five-Way Match Key Enablers

- **RAN Hardware**
- **RAN Software**
- **Fiber Transport**
- **SDN Core (transitioning to Edge)**
- **Devices**

© 2018 AT&T Intellectual Property. All rights reserved. AT&T, Globe logo, Mobilizing Your World and DIRECTV are registered trademarks and service marks of AT&T Intellectual Property and/or AT&T affiliated companies. All other marks are the property of their respective owners. AT&T Proprietary (Internal Use Only). Not for use or disclosure outside the AT&T companies except under written agreement.
First 5G Business Customer Trial  
**OCTOBER 2016**

Expanded Multi-City 5G Trials  
**SUMMER 2017**

New 5G testbed  
**AUSTIN, TEXAS**

Commercial Launch  
**Atlanta, Dallas, Waco 2018**
Wireless speeds of 1.2 Gbps in a 400 MHz channel

RAN Latency rates at 9-12 milliseconds

Our 5G millimeter wave solution effectively delivered into a building
No impacts on 5G mmWave signal performance due weather

mmWave signals can penetrate materials better than anticipated

1 Gbps speeds under line of sight conditions up to 900 feet

Full end-to-end 5G network architecture
CHALLENGES & OPPORTUNITIES

Emerging Real-time Applications

- Virtual Reality
- Field Force Automation
- Drones
- IoT
- Self-Driving & Connected Cars
- Tele-Medicine

© 2018 AT&T Intellectual Property. All Rights Reserved. AT&T, the Globe logo, Mobilizing Your World and DirecTV are registered trademarks and service marks of AT&T Intellectual Property and/or AT&T affiliated companies. All other marks are the property of their respective owners.
EDGECOMPUTEENABLES
EFFICIENTOFFLOADINGFOR
AUTONOMOUSCARS

- LIDAR
- Short range sensors
- Cameras
- Machine learning software
- Visual recognition
- Image Mapping
- Edge analytics
- Real-time traffic updates
- Software updates
- Entertainment
- Advanced data analytics
- 360 sensor scans
- V2V / V2X
- Local compute (parking assist, stop/start, etc.)
- Natural language processing

Challenging Ultra-Dense RF Environment
Satellite and terrestrial-based broadcast, V2X/V2V, 2.4/5 GHz Wi-Fi, BlueTooth®, CBRS, Cellular, LMR, Amateur Radio, CB

Key Interference Characteristics
1. Spectral Adjacency
2. Harmonics
3. Intermodulation

Source: Intel, Google, McKinsey, AT&T Corporate Strategy

© 2018 AT&T Intellectual Property. All rights reserved. AT&T, Globe logo, Mobilizing Your World and DIRECTV are registered trademarks and service marks of AT&T Intellectual Property and/or AT&T affiliated companies. All other marks are the property of their respective owners. AT&T Proprietary (Internal Use Only). Not for use or disclosure outside the AT&T companies except under written agreement.
Site has already had filter installed to remediate Broadcaster Interference issue. The shape of its current data indicates that this did not solve the problem -> this could be an auto-check

Site is confirmed to have Harmonic Interference.
• Signals reflected by excited defrosters from the car rear windows in surrounding lots.

• This issue forced relocation of the site.

• Interpreting a signature from cases like these might enable us to “trial” locations (with MOOs) before we do permanent installs.

• Saving money when these interesting, hard to diagnose cases do pop up