The future of cellular communication on transportation systems

and why we need 5G

Thomas Cooper
Director of Government Accounts
Traffic Technology Services, Inc
Connected Cars Landscape

**Consumer (107)**
- EV Charging (3)
- Ride Sharing/Carpooling (6)
- On Demand Rentals (11)
- Infotainment Interface (15)
- Car Sharing (9)
- Delivery (6)

**Enterprise (72)**
- Routing Optimization (3)
- Fleet Tracking & Asset Management (20)
- Telematic Service Providers (19)
- Security (2)
- Smart Cities (8)
- Usage-Based Insurance (9)

**Apps - Location - Data (44)**
- Infotainment Applications (9)
- Big Data (6)
- App Platform (11)
- Driver Behavior (14)
- Location/Navigation (14)

**Things (54)**
- Wearables (2)
- Sensors/Hardware (10)
- Heads Up Display (3)
- Vehicle to Infrastructure (1)
- Infotainment Embedded (16)
- Dongle (19)
THE COMING FLOOD OF DATA IN AUTONOMOUS VEHICLES

- **RADAR**: ~10-100 KB per second
- **SONAR**: ~10-100 KB per second
- **GPS**: ~50 KB per second
- **CAMERAS**: ~20-40 MB per second
- **LIDAR**: ~10-70 MB per second

**AUTONOMOUS VEHICLES**

4,000 GB per day... each day
Everything You Need to Know About 5G - IEEE Youtube Video
5G Requirements are Dictated by the Laws of Physics

\[ C = B \log_2 \left( 1 + \frac{S}{N} \right) \]

Higher frequencies are required for higher throughout and lower latency than existing cellular spectra.
Higher frequencies have less penetration (and high free space path loss).
Higher frequencies require more assets to cover smaller coverage areas with greater channel re-use.
### Base Station Types

#### Diagram
- **Suburban**
- **Urban**
- **In-Building**

#### Table

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Output Power (W)</th>
<th>Cell Radius (km)</th>
<th>Users</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femtocell</td>
<td>0.001 to 0.25</td>
<td>0.010 to 0.1</td>
<td>1 to 30</td>
<td>Indoor</td>
</tr>
<tr>
<td>Pico Cell</td>
<td>0.25 to 1</td>
<td>0.1 to 0.2</td>
<td>30 to 100</td>
<td>Indoor/Outdoor</td>
</tr>
<tr>
<td>Micro Cell</td>
<td>1 to 10</td>
<td>0.2 to 2.0</td>
<td>100 to 2000</td>
<td>Indoor/Outdoor</td>
</tr>
<tr>
<td>Macro Cell</td>
<td>10 to &gt;50</td>
<td>&gt;8 to 30</td>
<td>&gt;2000</td>
<td>Outdoor</td>
</tr>
</tbody>
</table>

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WILL YOUR FRONT YARD BE A 5G CELL TOWER SITE?
Stakeholder Perspectives
**Transportation Agency Perspective: 5G Networks will Enable Advanced TSMO Strategies**

- Traffic incident management - Onboard and roadside vehicle cameras and sensors will provide real-time, localized, actionable information for operators (human and/or virtual).

- Traffic signal coordination - instrumented vehicles will be probes and detectors that can drive ATMS actions.
<table>
<thead>
<tr>
<th>TSMO Category</th>
<th>Services Enhanced by 5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit signal priority</td>
<td>Extension of range and additional data points in decision making</td>
</tr>
<tr>
<td>Freight management</td>
<td>Route optimization, congestion reduction, congestion pricing scenarios</td>
</tr>
<tr>
<td>Work zone management</td>
<td>Vehicle operator alerts, route option guidance, platoon control</td>
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<tr>
<td>Special or unexpected event</td>
<td>Integration of ICM, ATMS, other systems with real-time data collection</td>
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<tr>
<td>management</td>
<td></td>
</tr>
<tr>
<td>Road weather management</td>
<td>On-board sensors to detect icing, etc. roadway treatment and plow dispatch.</td>
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<tr>
<td>Congestion pricing</td>
<td>Route options and incentives based upon cost structure and current demand and constraints</td>
</tr>
<tr>
<td>Managed lanes</td>
<td>Capacity optimization based upon historical and real-time data and analytics</td>
</tr>
<tr>
<td>Ridesharing programs</td>
<td>Standalone and multi-modal option inclusion</td>
</tr>
<tr>
<td>Parking management</td>
<td>Onboard cameras/sensors to determine availability</td>
</tr>
<tr>
<td>Rail crossing integration</td>
<td>Advance notice of crossing arrivals and durations tied to ATMS-motorist info display, alternate route guidance</td>
</tr>
<tr>
<td>Proactive Roadway Maintenance</td>
<td>On-board sensors detecting potholes, cracks, etc. automated work-order generation</td>
</tr>
</tbody>
</table>
Communications Carrier Perspective: 5G Networks are Required to Support Consumer Demand

Existing Cellular Infrastructure is often at Capacity for Current Data Demand

Future Applications will depend upon higher throughout and lower latency

Networks will need to densify to provide effective coverage

Additional Spectrum will be required to support denser networks
Transportation System Operators Perspective: 5G Networks Will be Required to Deliver Future, Integrated Services

- Capacity Utilization
- Incremental Revenue Capture (ridership and sensor data)
- Maintenance Management
- Schedule Notification and Adherence
Vehicle Manufacturer Perspective: 5G Networks will be Required to Support Future Features, Functionality and Affordability

- Feature Set Differentiation - Purchasers making buy decisions based on technical features as much as performance i.e. Traffic Light Information delivery by TTS

- Additional Revenue Streams from Data and Analytics
  - Parking spot occupancy, pot hole detection, roadway conditions, live probe data from vehicles

- Central Repository for refining and evolving autonomous vehicle decision algorithms

- Reducing price points for highly autonomous vehicles
  - Cloud-based intelligence

- Transition to Electric Vehicles

- “The Software Defined Car”
Freight Carrier Perspective: 5G Networks will be required to remain competitive

- Route Optimization- including least cost (delay, congestion pricing, etc)
- Internal Cost reductions (i.e. Migration to hybrid vehicles, traffic signal info to optimize drivetrain)
- Reduced Delivery Time and End-User Cost Reduction
The Traveler Perspective: 5G networks are Required for Cost-Effective Mobility as a Service

- Safer Travel Experience
- Democratization of Transportation Access Options (True MaaS)
- Predictability of Transportation Costs
- Overall Price Reductions (currently 16-19% of income)
Current communications networks are either at capacity and/or insufficient to support future throughput, coverage and latency requirements of emerging use cases.

Emerging use cases will require:
• Additional, higher-frequency spectrum options
• Network asset densification
• Additional Network asset attachment options

5G Networks will be the foundation for future of transportation requirements for all stakeholders in the transportation Ecosystem.