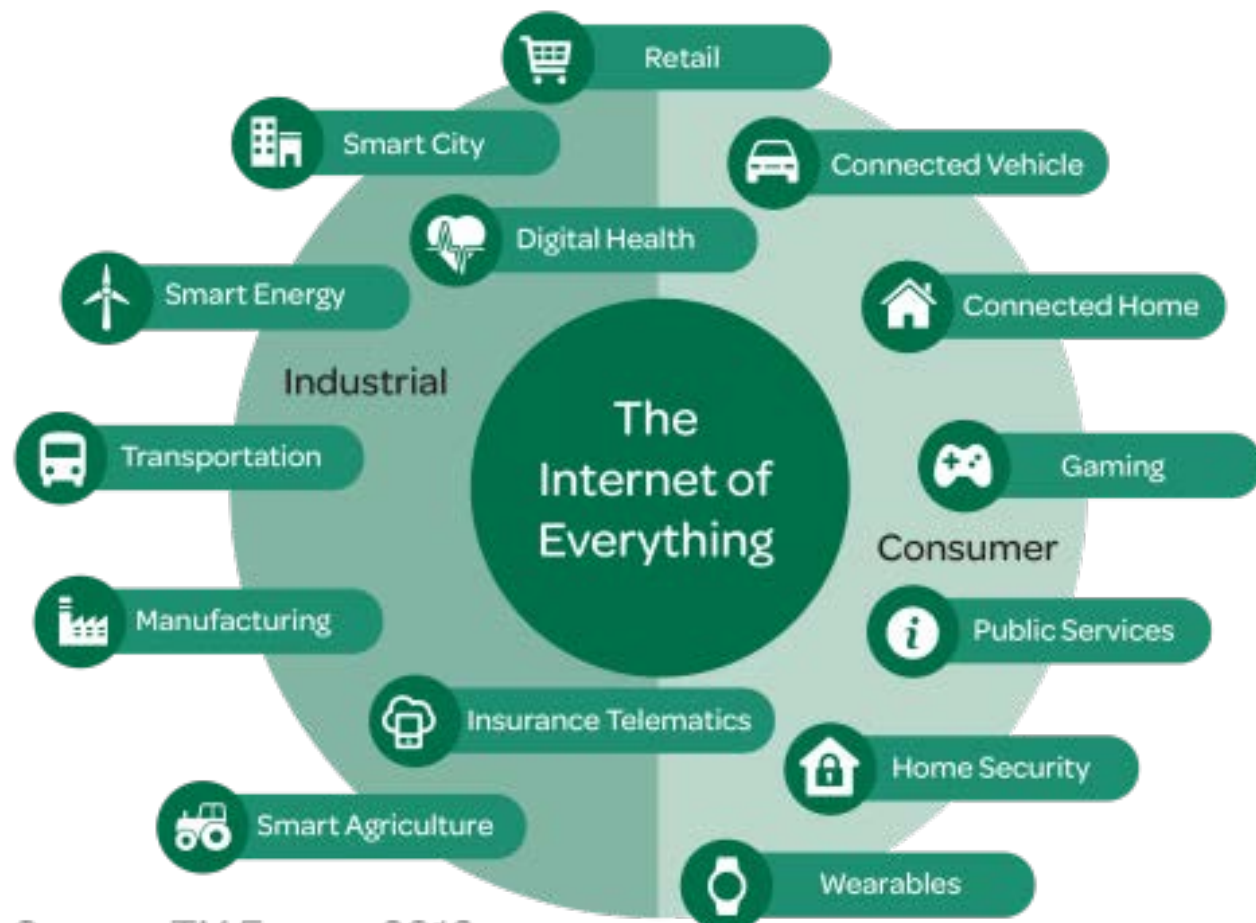


The future of cellular communication on transportation systems

and why we need 5G

Thomas Cooper
Director of Government Accounts
Traffic Technology Services, Inc



Source: TM Forum, 2016

Ubiquitous Health Care Service



IoT Service (Smart City)



Cloud Computing Service



Connected Car Service



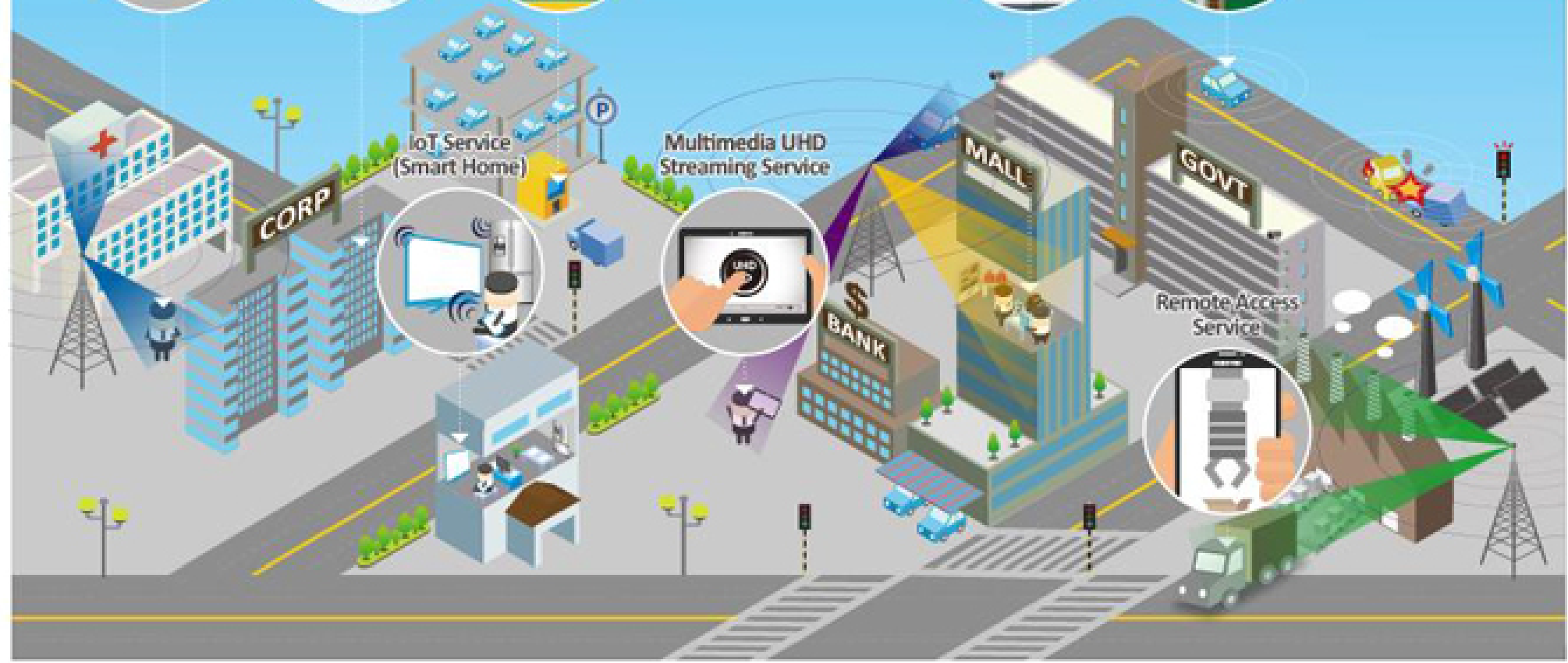
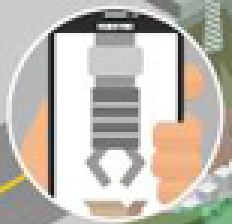
IoT Service (Smart Home)



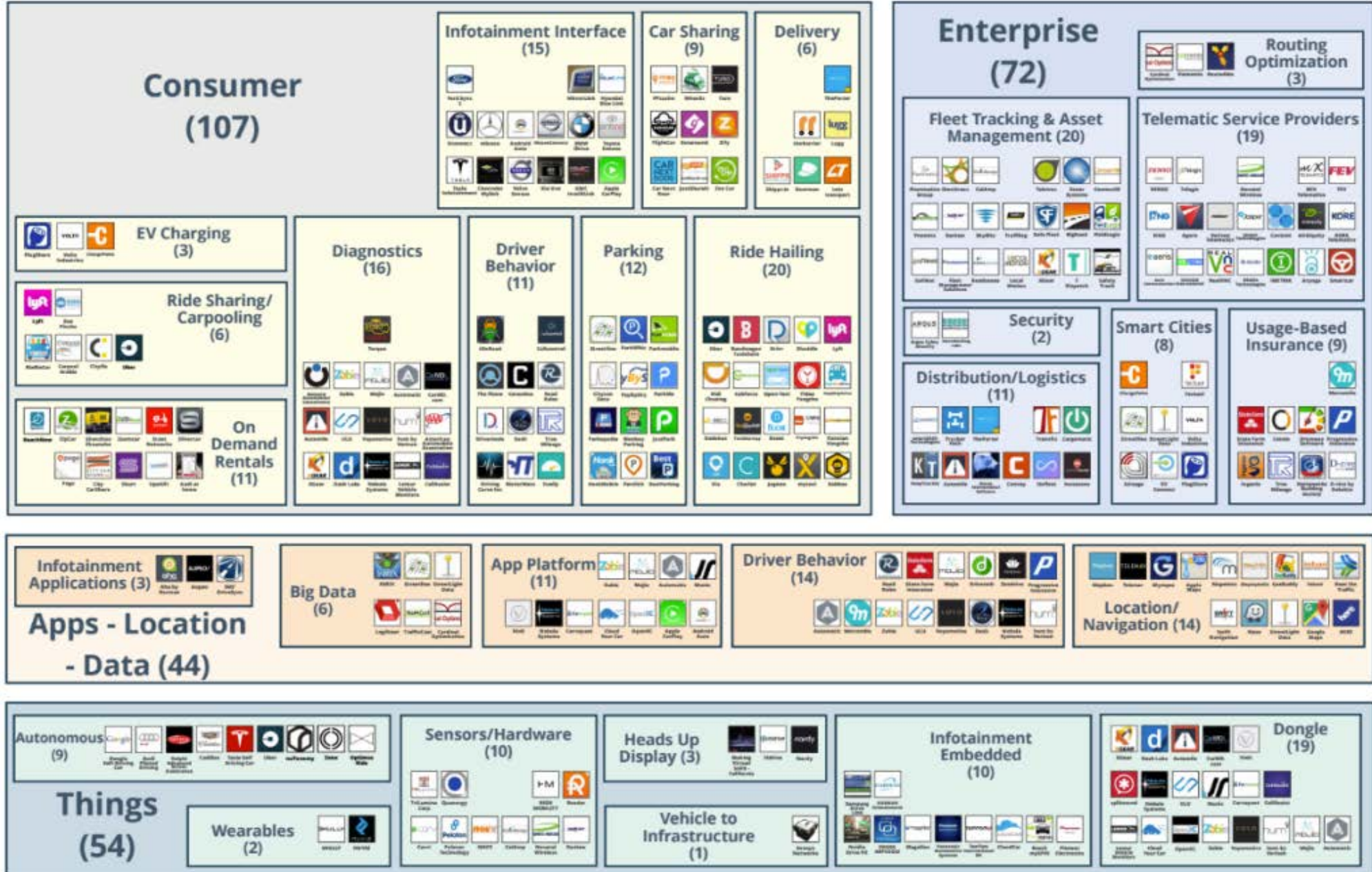
Multimedia UHD Streaming Service



Remote Access Service



Connected Cars Landscape



THE COMING FLOOD OF DATA IN AUTONOMOUS VEHICLES

RADAR
~10-100 KB
PER SECOND

SONAR
~10-100 KB
PER SECOND

GPS
~50KB
PER SECOND

CAMERAS
~20-40 MB
PER SECOND

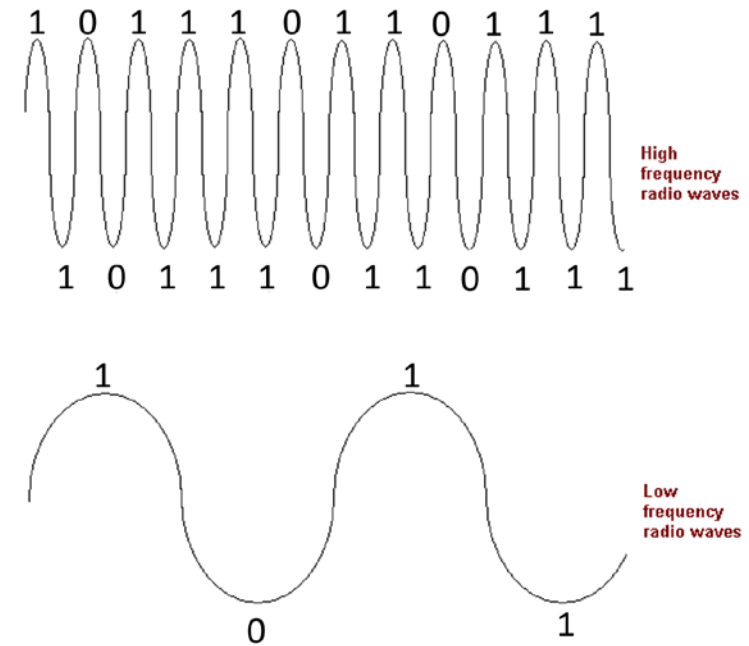
LIDAR
~10-70 MB
PER SECOND

AUTONOMOUS VEHICLES
4,000 GB
PER DAY... EACH DAY



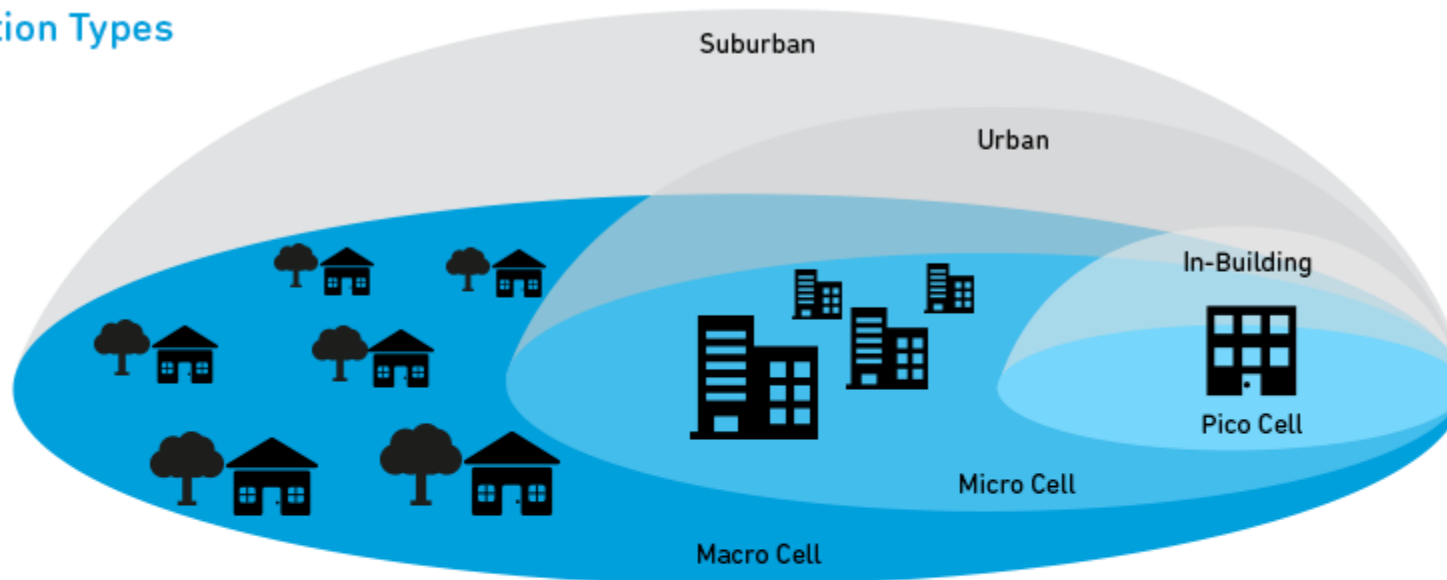
5G Requirements are Dictated by the Laws of Physics

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



Higher frequencies are required for higher throughput 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



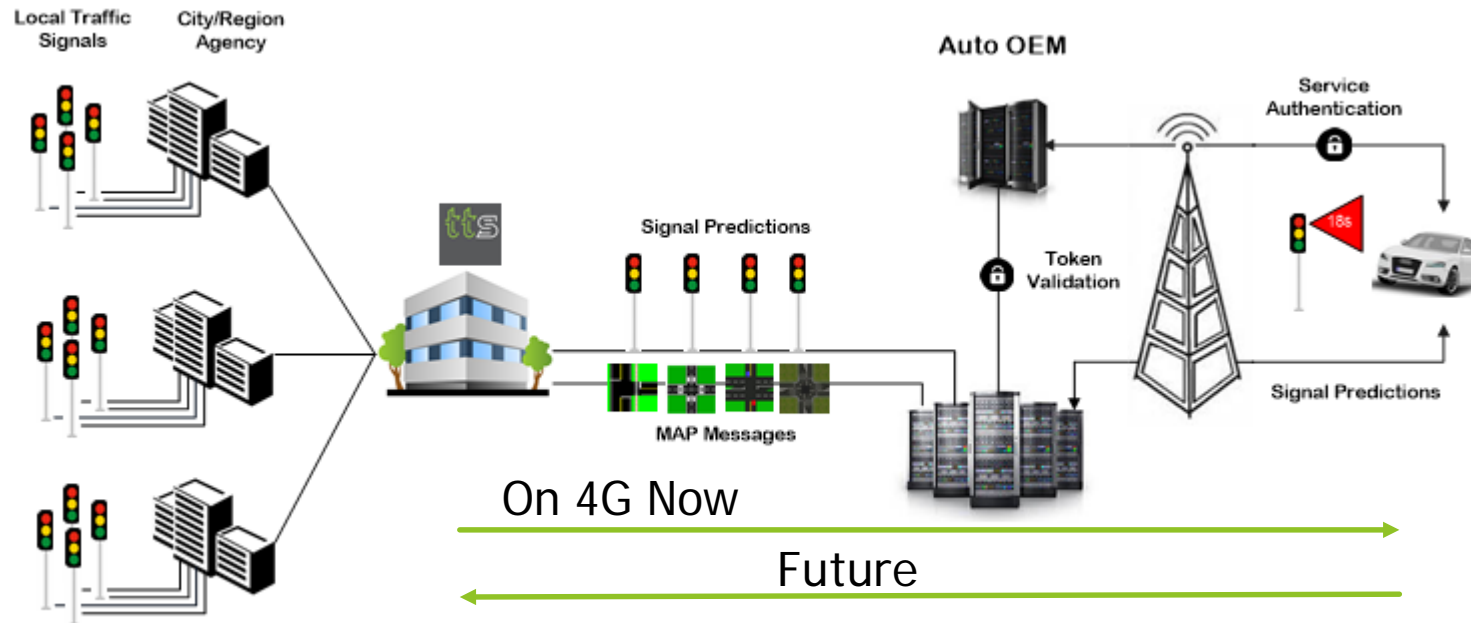
Cell Type	Output Power (W)	Cell Radius (km)	Users	Locations
Femtocell	0.001 to 0.25	0.010 to 0.1	1 to 30	Indoor
Pico Cell	0.25 to 1	0.1 to 0.2	30 to 100	Indoor/Outdoor
Micro Cell	1 to 10	0.2 to 2.0	100 to 2000	Indoor/Outdoor
Macro Cell	10 to >50	8 to 30	>2000	Outdoor



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.



TSMO Category	Services Enhanced by 5G
Transit signal priority	Extension of range and additional data points in decision making
Freight management	Route optimization, congestion reduction, congestion pricing scenarios
Work zone management	Vehicle operator alerts, route option guidance, platoon control
Special or unexpected event management	Integration of ICM, ATMS, other systems with real-time data collection
Road weather management	On-board sensors to detect icing, etc. roadway treatment and plow dispatch.
Congestion pricing	Route options and incentives based upon cost structure and current demand and constraints
Managed lanes	Capacity optimization based upon historical and real-time data and analytics
Ridesharing programs	Standalone and multi-modal option inclusion
Parking management	Onboard cameras/sensors to determine availability
Rail crossing integration	Advance notice of crossing arrivals and durations tied to ATMS-motorist info display, alternate route guidance
Proactive Roadway Maintenance	On-board sensors detecting potholes, cracks, etc. automated work-order generation

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 throughput 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

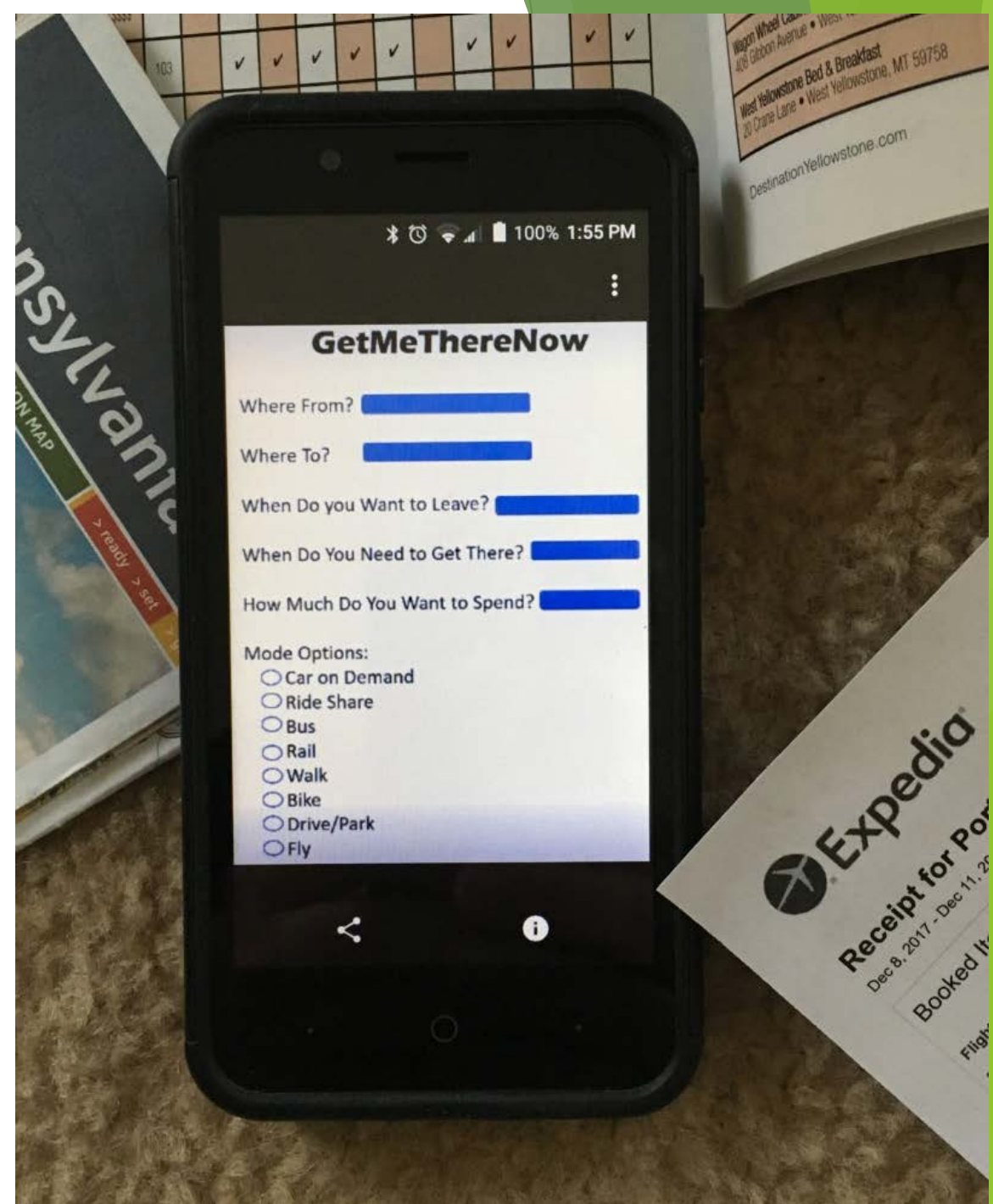
- Route Optimization- including least cost (delay, congestion pricing, etc)
- Internal Cost reductions (i.e. Migration to hybrid vehicles, traffic signal info to optimize drivetrain)
- Reduced Delivery Time and End-User Cost Reduction

amazon



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)

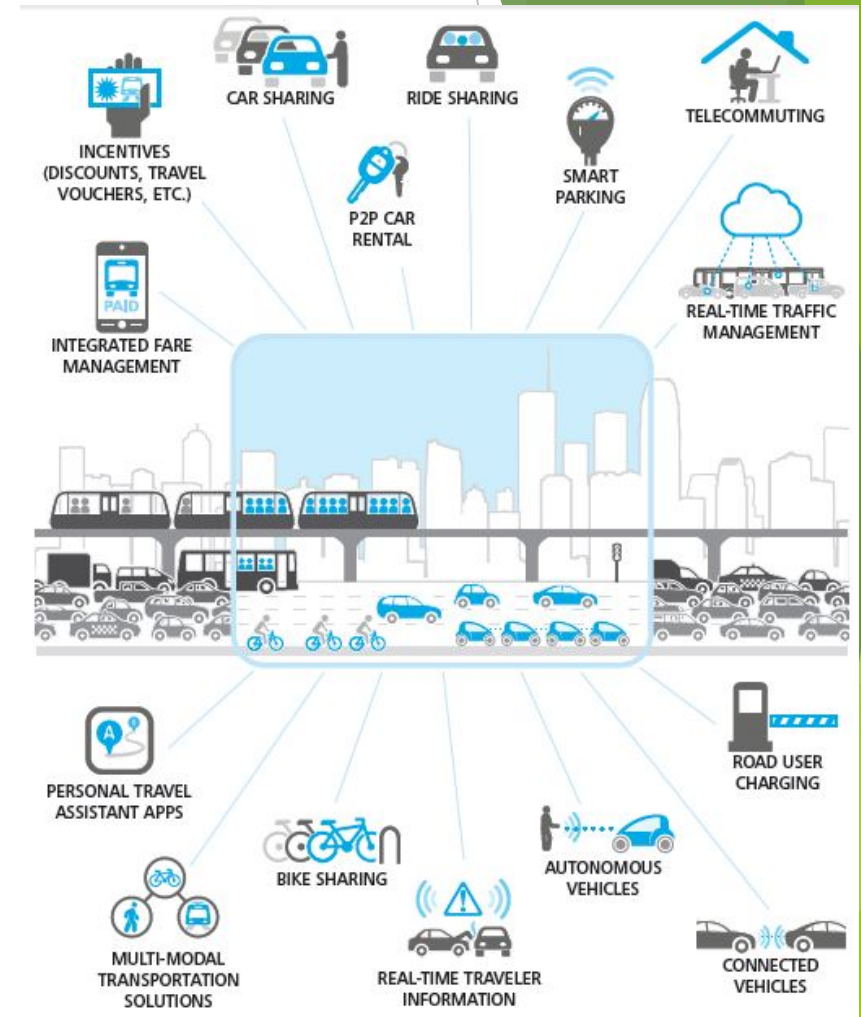


Current communications networks are either at capacity and/or insufficient to support future throughput, coverage and latency requirements of emerging use cases

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





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