



# Future of Connected Autonomous Vehicles in Smart Cities



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# Outline

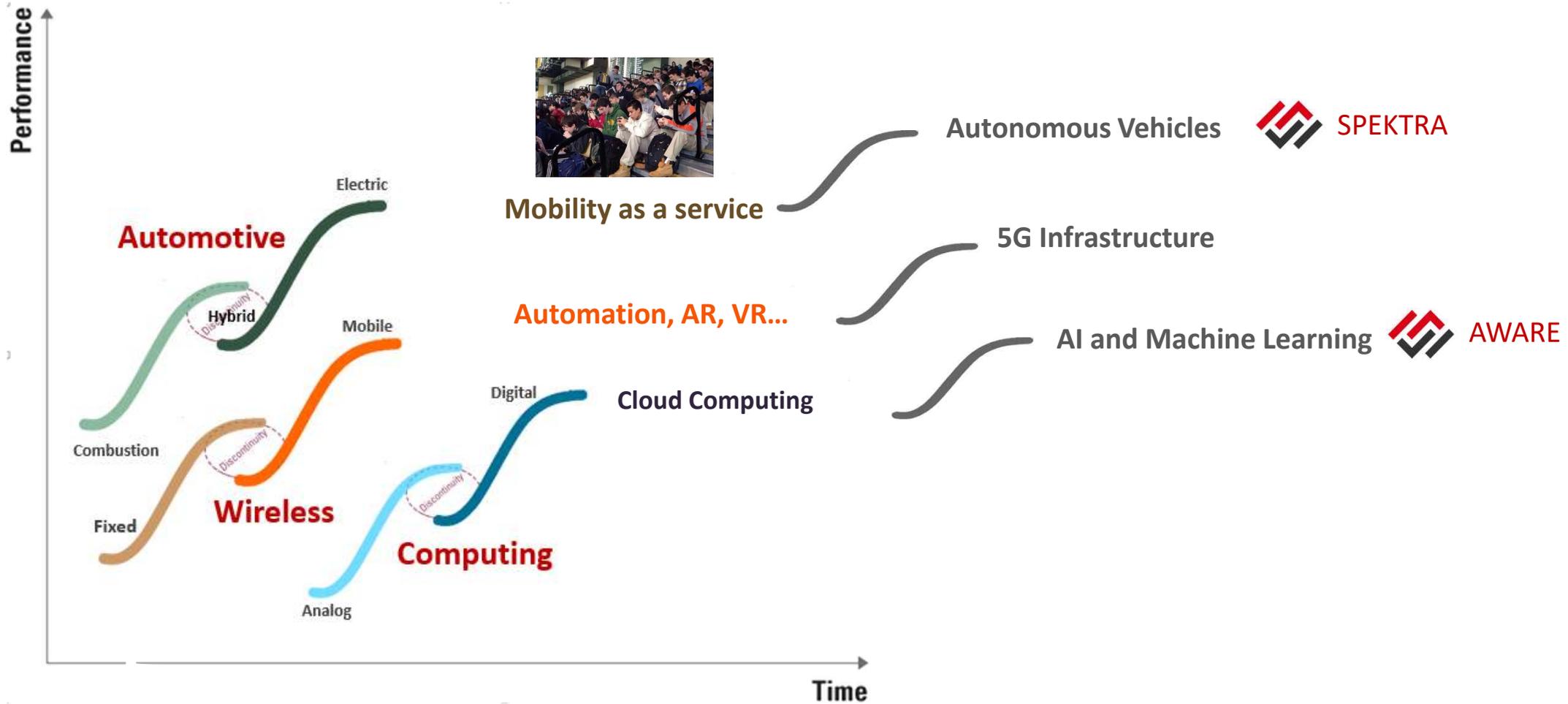
- › Automotive future is electrified, autonomous, shared, and connected
- › Role of 5G connectivity in mobility technology ecosystem
- › Connecting vehicles with transportation infrastructure (V2I)
- › Distributed edge compute versus centralized (V2X)
- › Seamless and transparent connectivity to riders during their journey
- › Next paradigm shifts: convergence between connectivity, mobility, and edge services/compute

# Crossroad between e-Mobility and Connectivity

- Unlimited 5G capacity
- Secure, reliable, and low-latency connections
- Novel edge-services
- Mobility as a Service
- Delivery of Goods
- Autonomous Vehicles (AV)
- Ground and Air
- Consumer Experience
- Safety ratings



# Riding Next Wave of Innovation and Disruption



# ADAS/AV Safety Levels

- Driver-in-the-loop  
OEM/Tier 1 must make sure driver can respond  
Liability on Driver
- Driver-out-of-the-loop  
Liability is on the OEM/Tier 1 and Mobility as Service Provider

- L0 – L3 are all driver-in-the-loop



- L4 – L5 are driver-out-of-the-loop

SAE J3016™ LEVELS OF DRIVING AUTOMATION					
SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
<p><b>You are driving</b> whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering</p>			<p><b>You are not driving</b> when these automated driving features are engaged – even if you are seated in “the driver’s seat”</p>		
<p>You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety</p>			<p>When the feature requests, you must drive</p>	<p>These automated driving features will not require you to take over driving</p>	

What does the human in the driver's seat have to do?



# The EV factor and Power Consumption

- > Waymo and CRUISE use more sensors
- > L2 vs future Robo-taxi L4
- > ADAS architectures will evolve with advanced imaging radars capabilities
- > Today is all about safety, tomorrow will be about power consumption and lower pricing..

	Camera	Long Range RADAR (typically 77GHz)	Short & Mid Range RADAR (typically 24GHz)	Ultrasounds (48 kHz)	LIDAR CMOS < 1µm	LIDAR SWIR > 1µm
Object detection	●	●	●	●	●	●
Object classification	●	●	●	●	●	●
Environment analysis	●	●	●	● (near)	●	●
Distance estimation	●	●	●	● (near)	●	●
Speed measurement	●	●	●	●	●	●
Object edge precision	●	●	●	●	●	●
Lane tracking	●	●	●	●	●	●
Range of visibility	●	●	●	●	●	●
Operation in bad weather	●	●	●	●	●	●
Operation in poor light conditions	●	●	●	●	●	●
Operation in dark	●	●	●	●	●	●

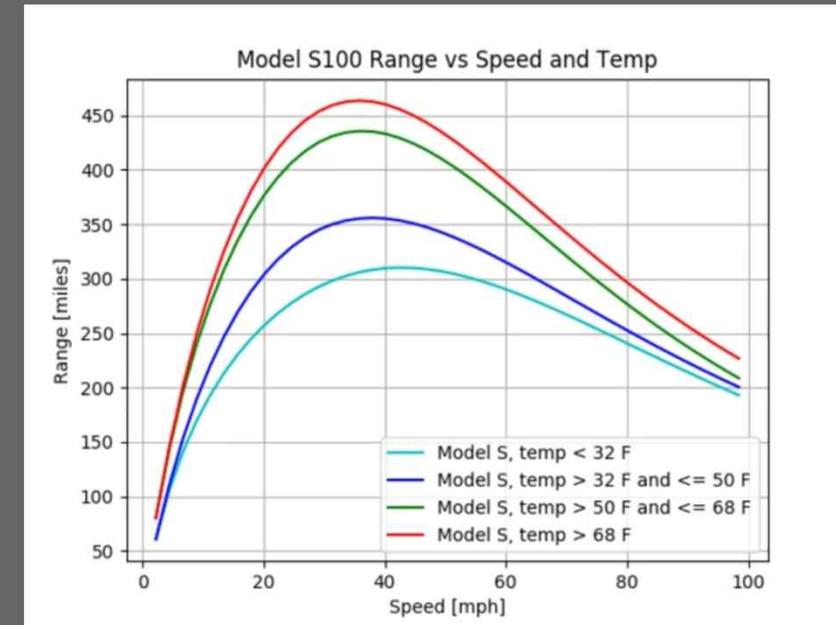
	Cameras	LIDAR	RADAR
<b>Tesla</b>	8	0	1
<b>Waymo</b>	8	3	4
<b>GM/Cruise</b>	16	5	21

<https://www.eetindia.co.in/adas-best-ways-to-make-vehicles-see/>

# The EV factor and Power Consumption

EV Car range is impacted by:

- Operating speed
- Outside temperature
- Driver in or out of the loop
- Tesla Model S range is reduced by 30% with Auto Pilot
- AI software stack can optimize EV range in L4

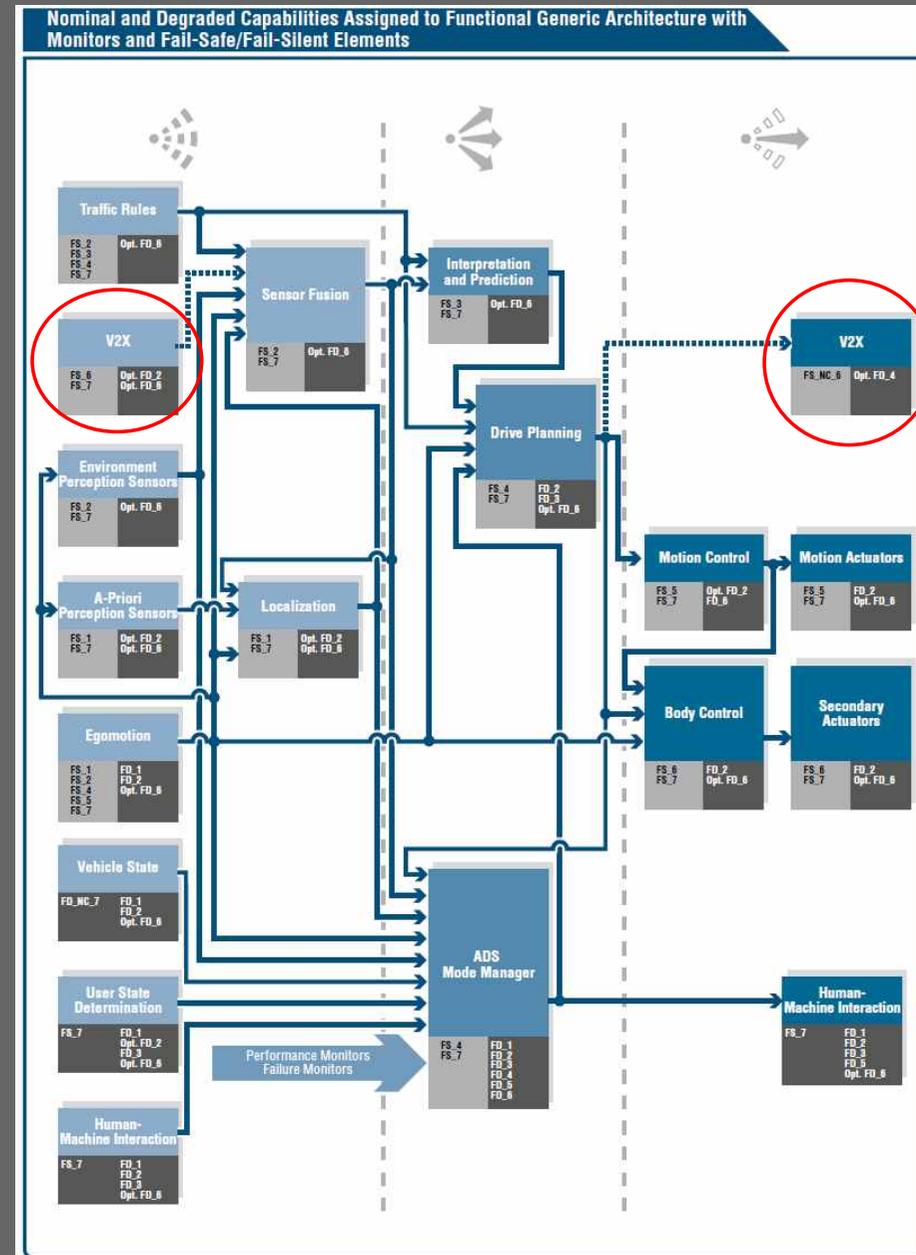


# Connected Cars and Smart Roads Open Loop Operation

- Example of open and closed loop system
- Dotted V2X lines are for Open Loop operation
- Human-machine interface is for Driver in the Loop

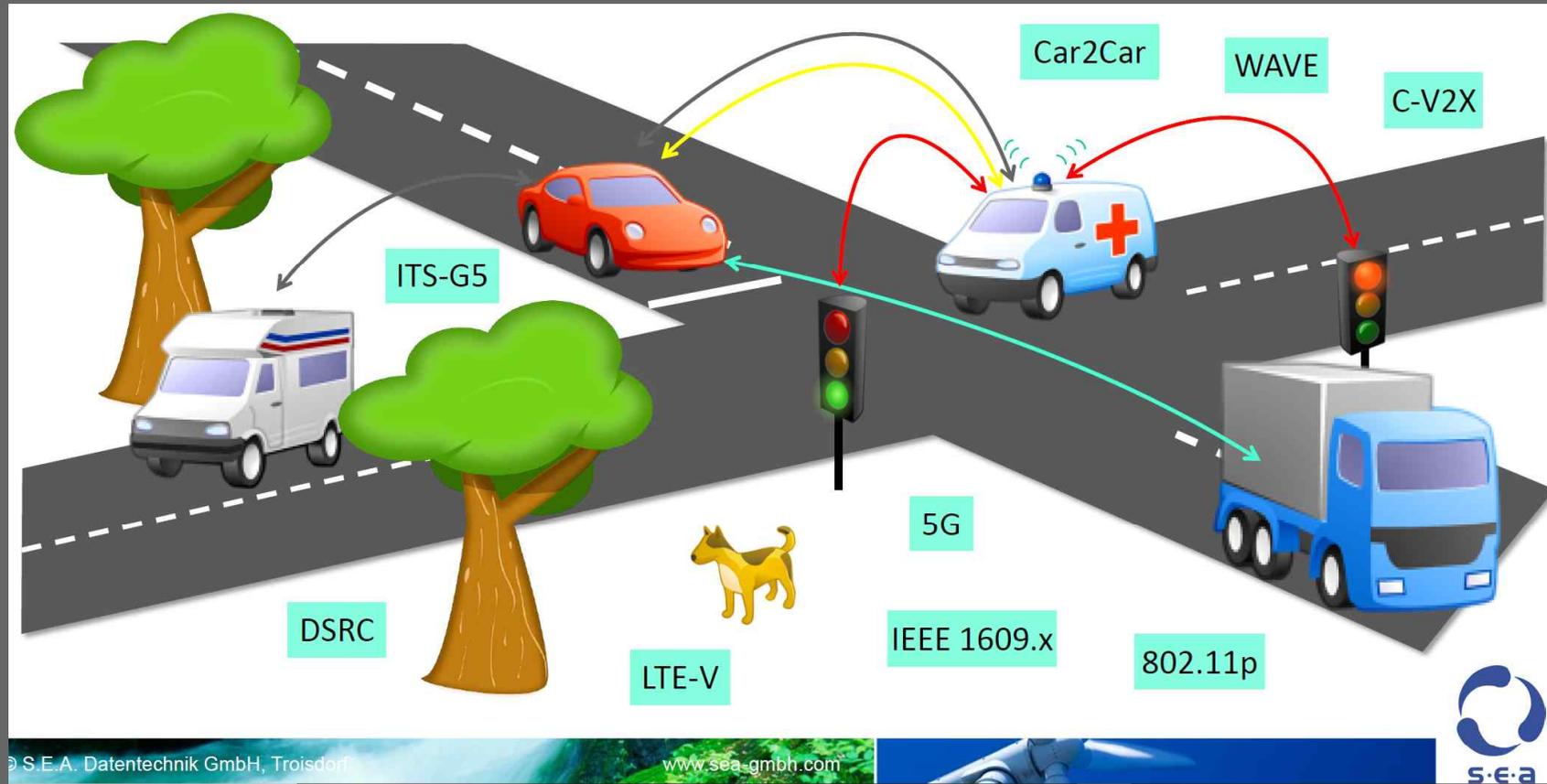
Term	Definition
<b>HARDWARE-IN-THE-CLOSED-LOOP (HIL)</b>	Target software is executed on target hardware, whereas the hardware outputs influence the hardware inputs.
<b>HARDWARE REPROCESSING (OPEN LOOP)</b>	Target software is executed on target hardware, whereas the hardware outputs do not influence the hardware inputs

<https://www.apiv.com/.../safety-first-for-automated-driving-apiv-white-paper.pdf>



# Connected Cars and Smart Roads Open Loop Operation

- No security breach
- ADAS
- V2X
- V2V
- V2I



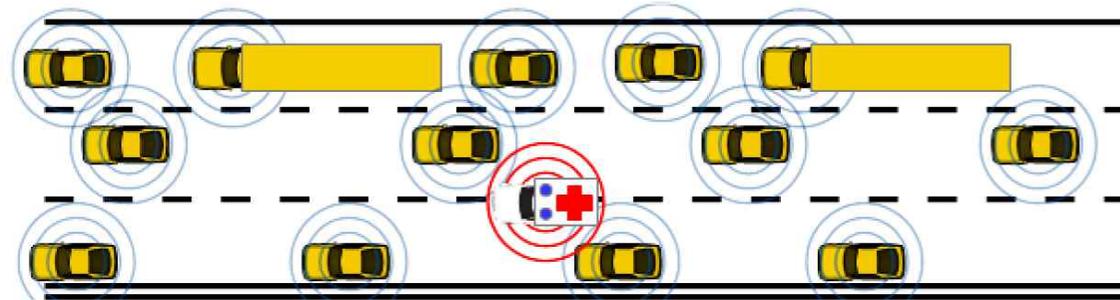
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www.sea-gmbh.com



# Connected Cars and Smart Roads Open Loop Operation

Priority/Emergency Vehicles

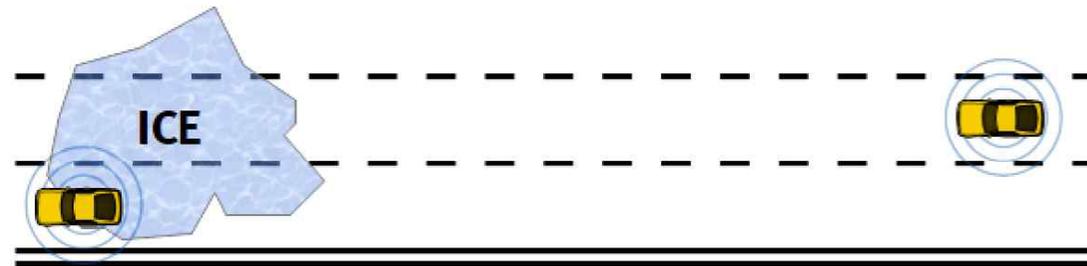


Road Side Unit



Road Hazard Warning  
(centralized/  
decentralized)

Message types:  
Road Condition (e.g. Ice)  
Accident Ahead  
In-Vehicle Signage  
Roadway Weather  
etc...



Road Sensor Station



- 5G Network Security
- 5G High Capacity
- 5G Low Latency

# Global Warming Factor

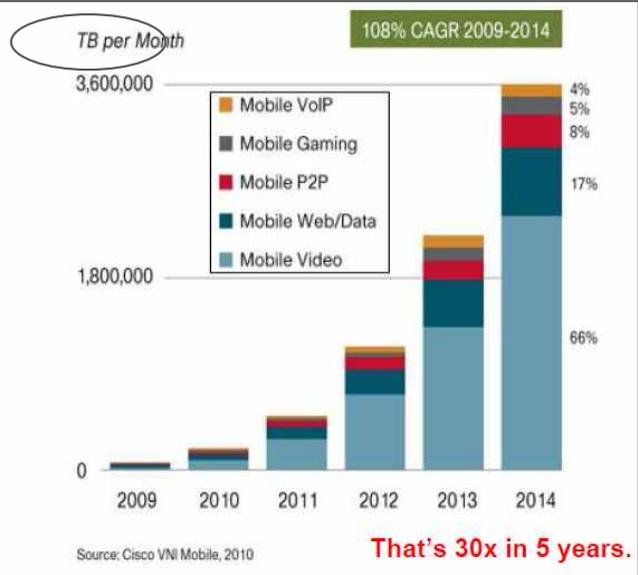
## Cisco VNI Mobile 2010

3+ Modes  
5+ Bands

5 000 000 towers

15 000 000 equivalent cars of CO<sub>2e</sub>

5 000 000 000 people without broadband

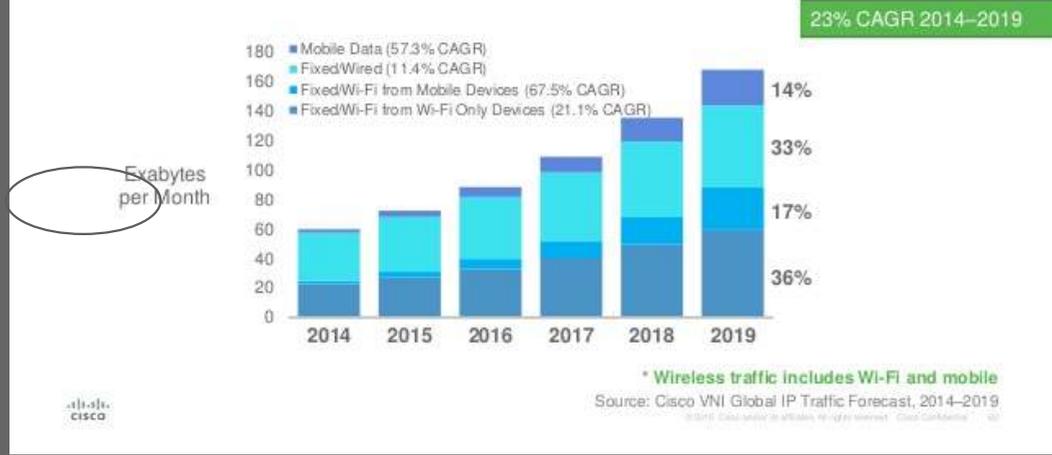


Not Counting Data Centers !

## Cisco VNI Mobile 2015

### Global IP Traffic by Local Access Technology

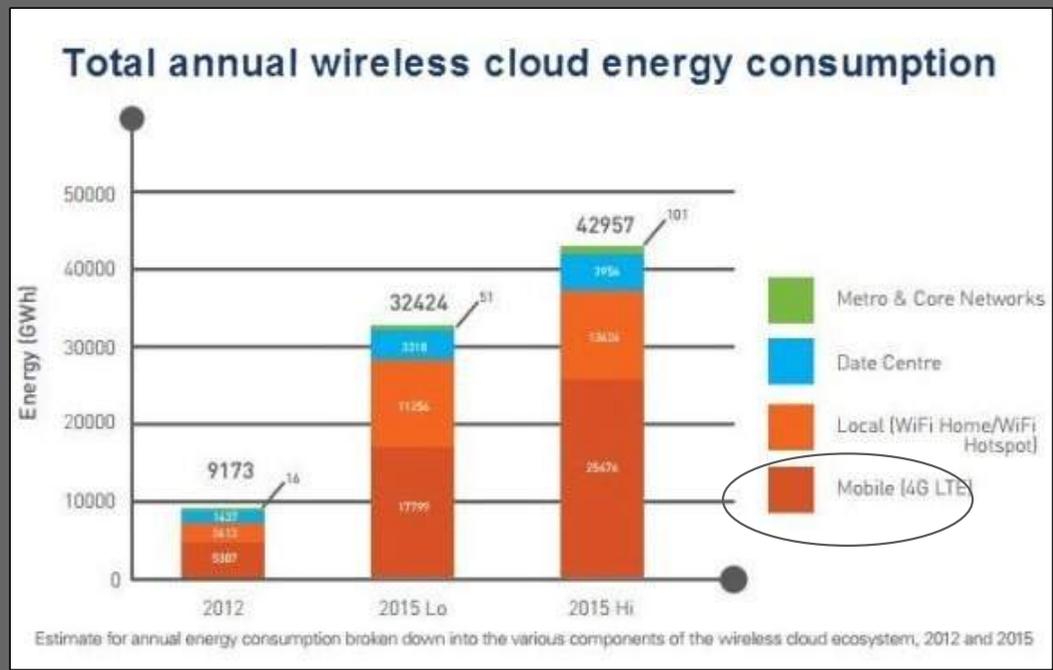
By 2019, Two-Thirds of Total IP Traffic Will Be Wireless\*



1 Exabyte = 1,000,000 Terabyte (TB)

# Wireless Networks Ecosystem

- Mobile Networks consumes most of energy
- 5G densification is 1,000x that of 4G LTE
- How can 5G infrastructure energy consumption be reduced?

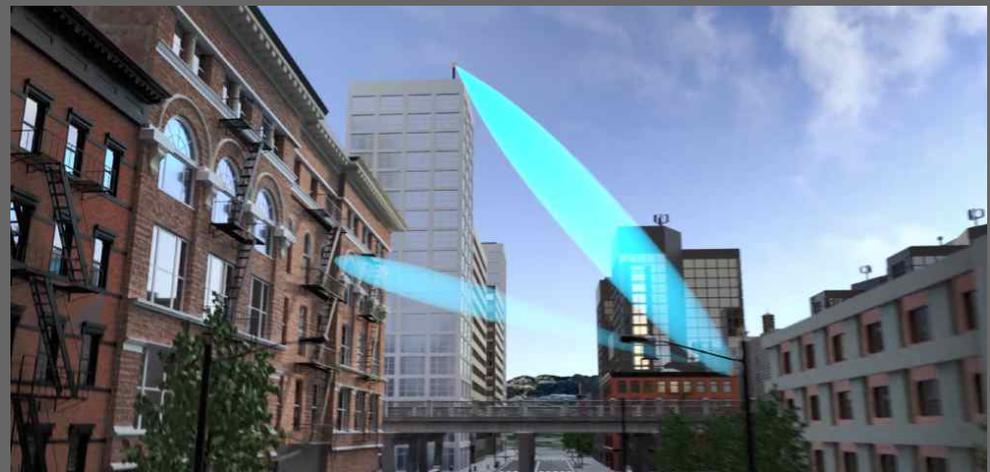


### Mobile Data Volume – 5G vs. 4G

<b>10</b> TERABYTES / S / SQ. KM <sup>2</sup>		<b>1/100</b> TERABYTES / S / SQ. KM <sup>2</sup>
<b>5G</b>		<b>4G</b>

# Metawave 5G Solutions

- ✓ Increasing Speed & Bandwidth
- ✓ Eliminating Indoor & Outdoor Dead zones
- ✓ Low Cost & Low Power Consumption
- ✓ Lightweight, Infrastructure-Light
- ✓ Enhanced Signal Amplification





Metawave is providing enhanced speed, bandwidth and connectivity through low cost, infrastructure-light deployments

*Capabilities for Increased 5G Coverage:*



**High-Performance Passive Reflector**

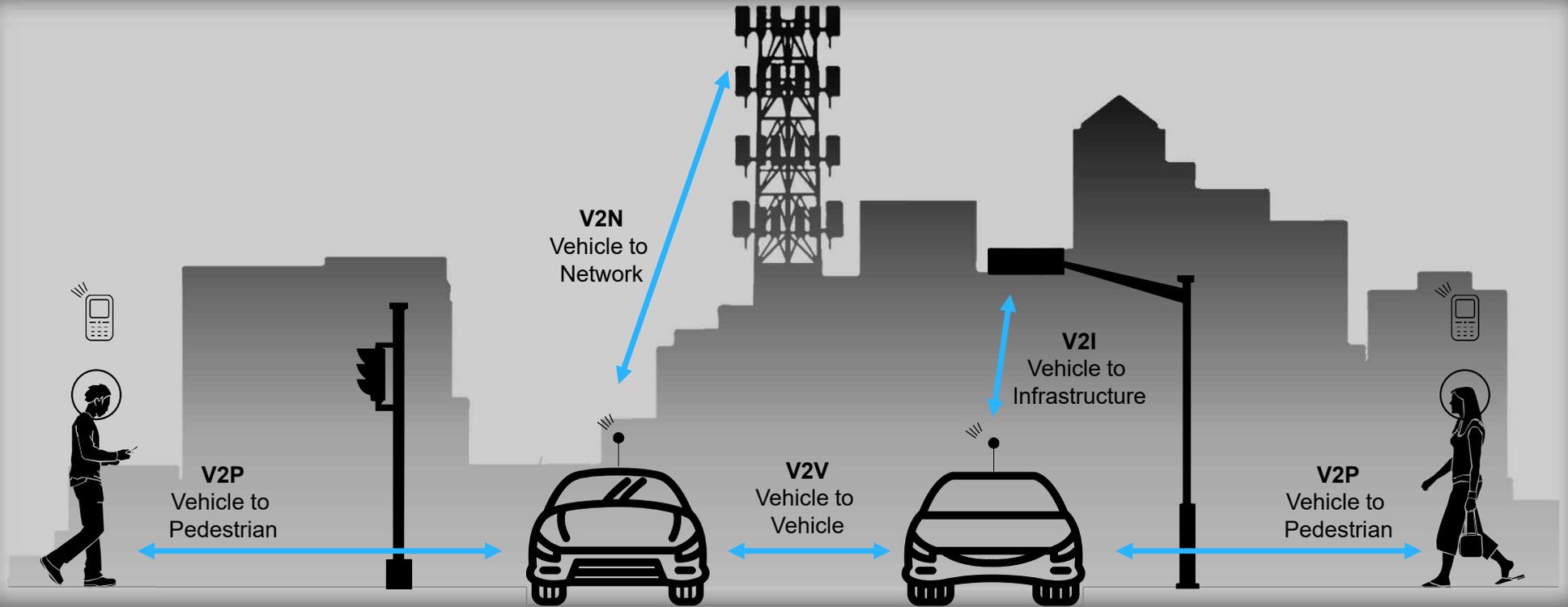
*50m+ increased range*



**High-Performance Active Analog Repeater**

*250m+ increased range*

# 5G Driving Massive New Opportunities Across Telecom Landscape



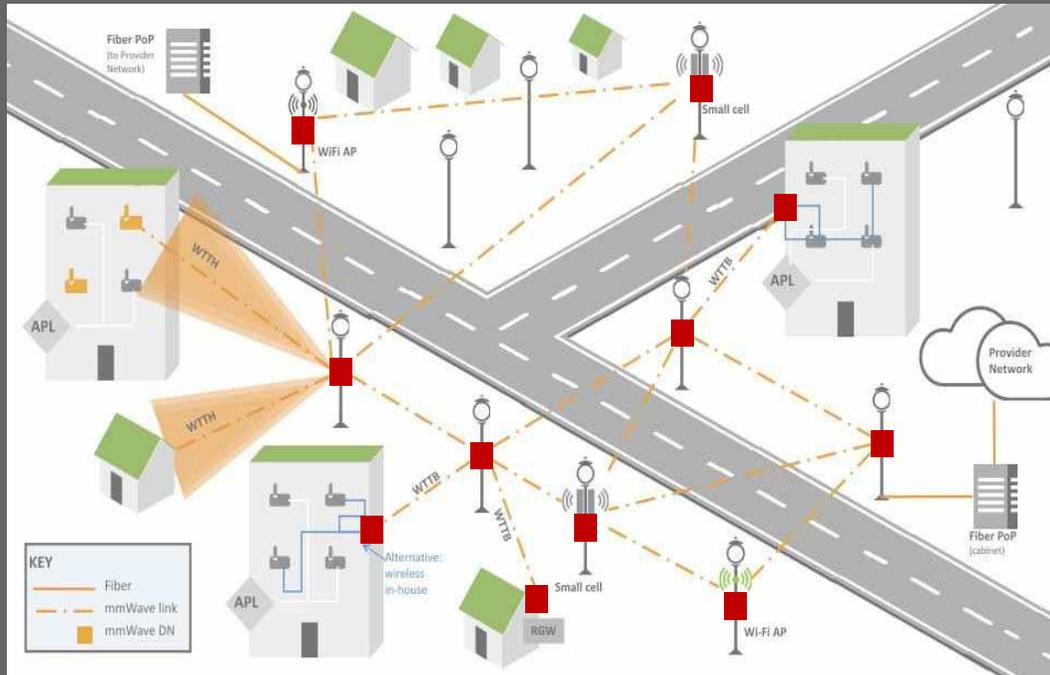
- ✓ 5G Offers New Use Cases
- ✓ 5G Lower Latency Applications Will Need Edge Cloud

- ✓ Move Toward Small Cells
- ✓ Enabling Open Radio Access Network (RAN)

# Integrated 5G Solutions Present Large Market Opportunity



*The Value Potential of the Internet of Things:  
9 settings culminate in a \$3.9T-\$11.1T annual impact by 2025*



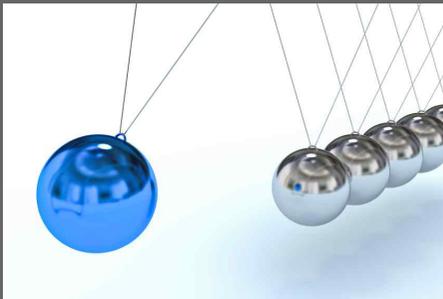
*Integrated Metawave Technology* ■

-   
**Vehicles**  
 Autonomous vehicles & condition-based maintenance  
**\$210B-\$740B**
-   
**Home**  
 Chore automation & security  
**\$200B-\$350B**
-   
**Offices**  
 Security & energy  
**\$70B-\$150B**
-   
**Cities**  
 Public health & transportation  
**\$930B-\$1.7T**
-   
**Worksites**  
 Operations optimization, health/safety  
**\$160B-\$930B**
-   
**Factories**  
 Operations & equipment optimization  
**\$1.2T-\$3.7T**
-   
**Outside**  
 Logistics & Navigation  
**\$560B-\$850B**
-   
**Human**  
 Health and fitness  
**\$170B-\$1.6T**
-   
**Retail Environment**  
 Automated checkout  
**\$410B-\$1.2T**

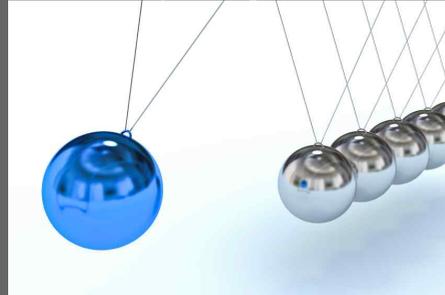
# Enterprise vs Consumer 5G

- 2G cellular networks were about **VOICE** services
- 3G cellular networks were about **DATA** services
- 4G cellular networks were about **APPS** services
- 5G cellular networks were about **real-time EDGE** services

2G, 3G, 4G RoI from Consumer because of WiFi



Initial 5G RoI from Enterprise replacing WiFi



## Metawave Passive KLONE Reflectors

- 24 to 60 GHz frequency bands
- Zero power without wiring
- 50m range extension
- Zero delay with friendlier to factory users
- Lowest CAPEX with increased coverage
- Ease of planning and Installation
- Zero OPEX with Universal Designs
- Measured gain 15-30 dB



## Active TURBO-2 Repeaters

- Small and Macro cell backhaul
- Remote access for configuration and monitoring during installation
- Extremely low delay < 5 nsec
- Easy installation and no required OPEX
- 250m+ range extension with adjustable up to 100+ dB gain
- Dynamically configuring antennas to lock on strongest signal strength by steering the beam



# Metawave's 5G / Telecom Go-to-Market Strategy

## Target 5G infrastructure vendors complemented by limited direct sales

- Sell / license KLONE & TURBO to 5G infrastructure vendors
- Passive relays based on meta-structures for outdoor and indoor network integration
- Urban network planning and support
- Indoor network planning and support



Office Buildings



Stadiums



Airports



Malls



Outdoor Dead Zones



Around the Corner



Non-line-of-sight Backhaul

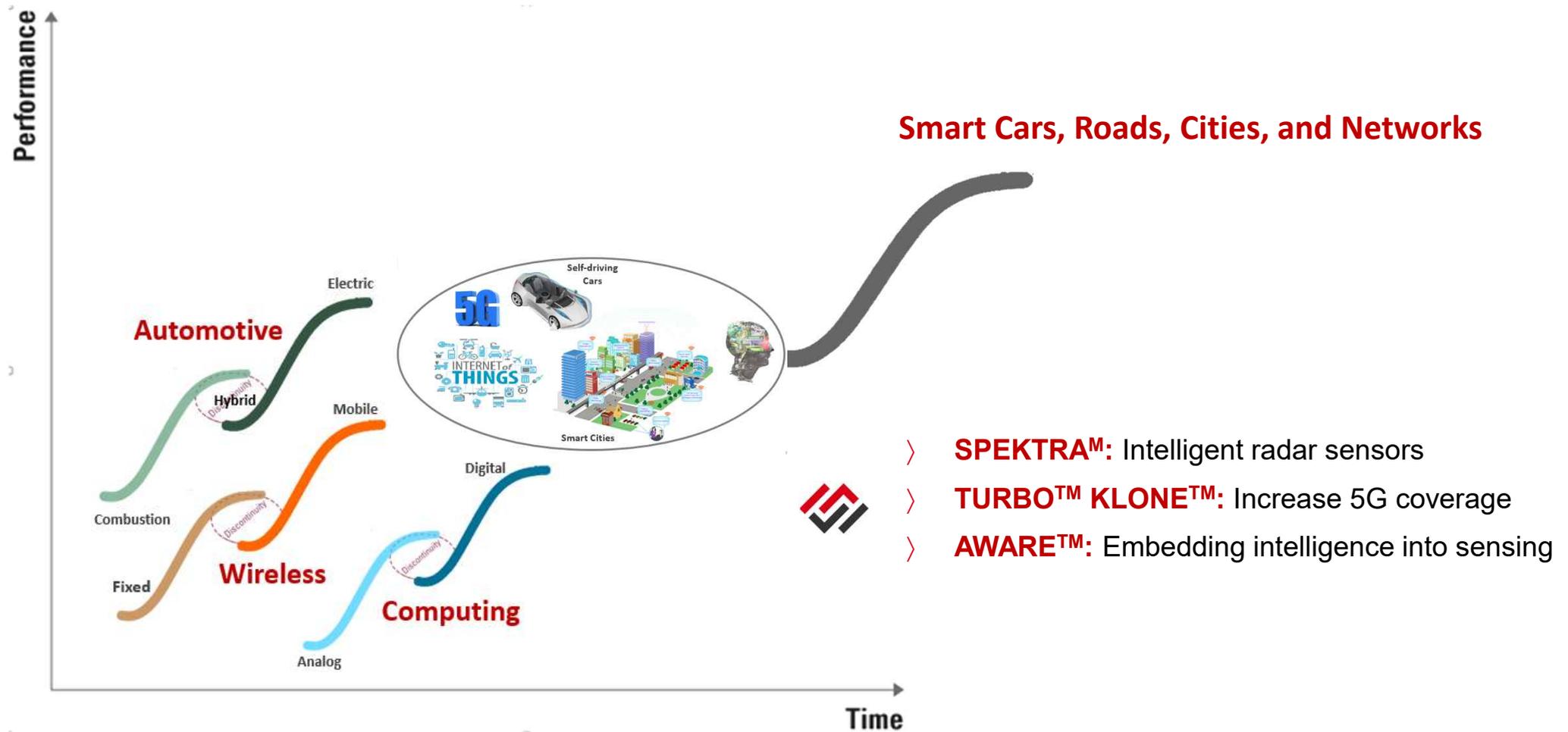
	Metawave Licensing KLONE Design to Partners -> Final Customer		Direct Sales and Support	
	Metawave	Partner	Metawave	Customer
Site Planning		✓		✓
Scanning for 3D Maps		✓	✓	✓
E&M Modeling		✓	✓	
KLONE Design Selection		✓	✓	✓
New KLONE Design	✓		✓	
Manufacture, Assembly & Testing		✓	✓	
Installation		✓		✓

# Mobility 2030: Beyond transportation (KPMG)



<https://www.youtube.com/watch?v=4B7mZFU2sB4>

# Next Paradigm Shift



# Thank You

