

**WSTS 2013, San Jose'**

# The Smart and Connected Vehicle and the Internet of Things

Flavio Bonomi  
Cisco Fellow, Vice President

and Many Others

Advanced Architecture and Research  
Cisco Systems



# Agenda

- An Introduction to the Internet of Things
- The Future Infrastructure for the Internet of Things
- The Connected Vehicle and Intelligent Transportation
- Enabling Technologies
- Conclusions

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- **An Introduction to the Internet of Things**
- The Future Infrastructure for the Internet of Things
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# The Internet of Everything

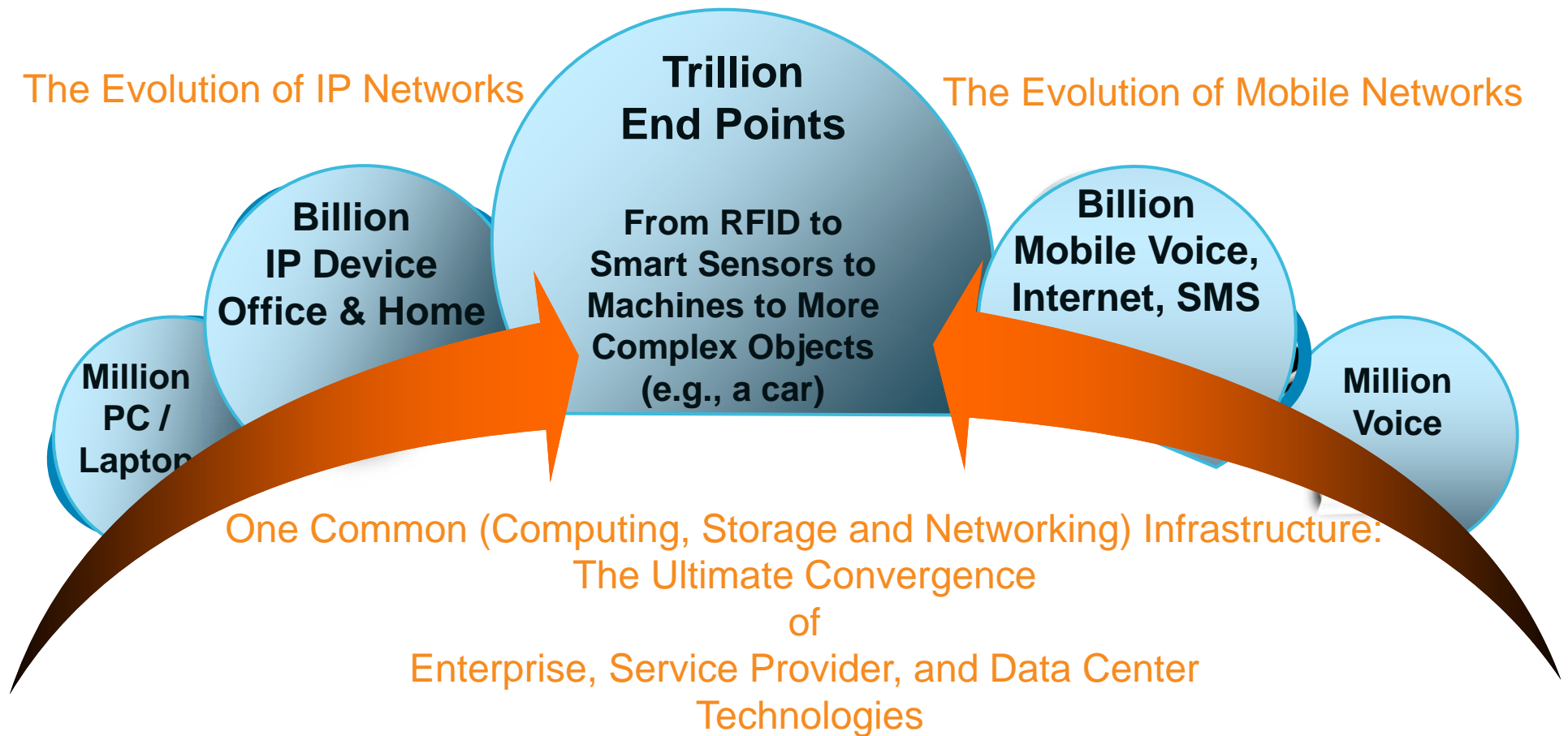
How the Internet of Everything Will Change  
the World...for the Better

White Paper at:  
[http://www.cisco.com/web/about/  
ac79/docs/innov/IoE\\_Economy.p  
df](http://www.cisco.com/web/about/ac79/docs/innov/IoE_Economy.pdf)

**14.4 Trillion  
Dollars by  
2022**

A good way to go beyond the “naming” confusion:  
(IoT, M2M, Cyber-Physical Systems, Intelligent Systems,  
Industrial Internet, Connected Devices, etc., etc.)

# The Internet of Things (or of Everything): The Convergent Evolution of IP and Mobile Networks



## “The IoT Computer”

# A Broad Set of Applications

## Energy Saving (I2E)

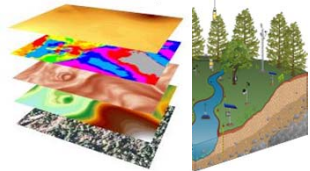


## Intelligent Buildings

## Defense



## Predictive maintenance



## Enable New Knowledge



## Agriculture

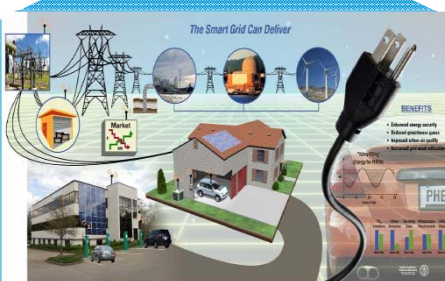
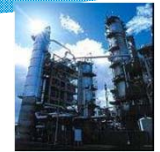


## Transportation and Connected Vehicles

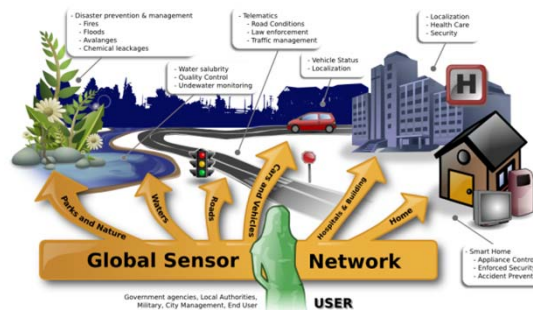


## Healthcare

## Enhance Safety & Security



## Smart Grid



## Smart City



## Smart Home

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# The “Common” IoE Infrastructure Architecture: Is it like this ?

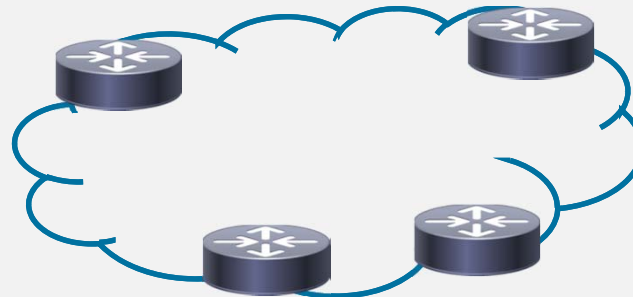
## Data Center Cloud

Application Hosting,  
Management



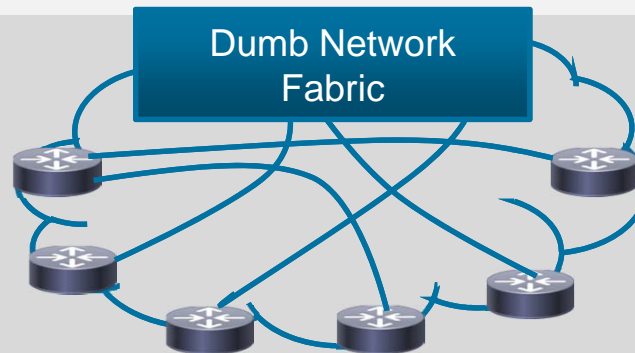
## Core

IP/MPLS, QoS, Multicast,  
Security, Network Services,  
Mobile Packet Core



## Multi-Service Edge

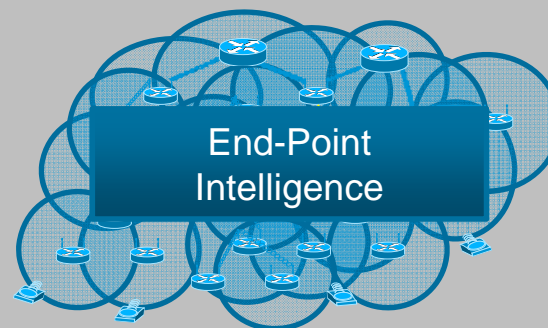
3G/4G/LTE/WiFi/  
Ethernet/PLC



## Embedded Systems and Sensors

smart and less smart  
things, vehicles, machines

Wired or Wireless





# The IoT Computing, Storage and Networking Platform Basic Architecture

## Data Center Cloud

Application Hosting,  
Management



## Core

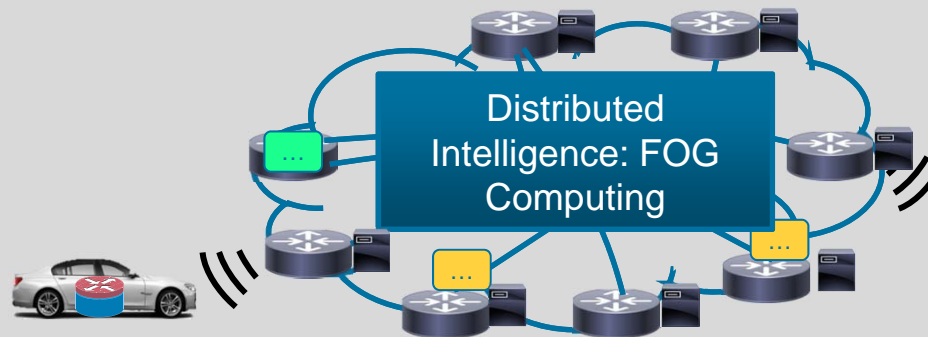
IP/MPLS, QoS, Multicast,  
Security, Network Services,  
Mobile Packet Core



IP/MPLS Core

## Multi-Service Edge

3G/4G/LTE/WiFi/  
Ethernet/PLC

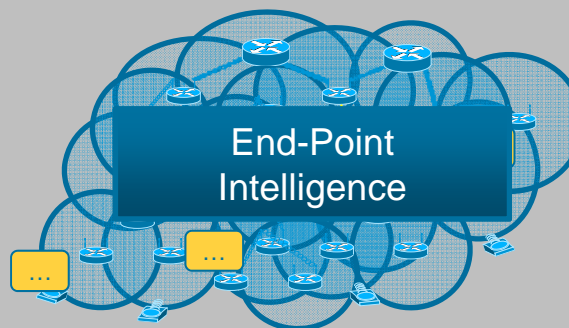


Field Area Network

## Embedded Systems and Sensors

smart and less smart  
things, vehicles, machines

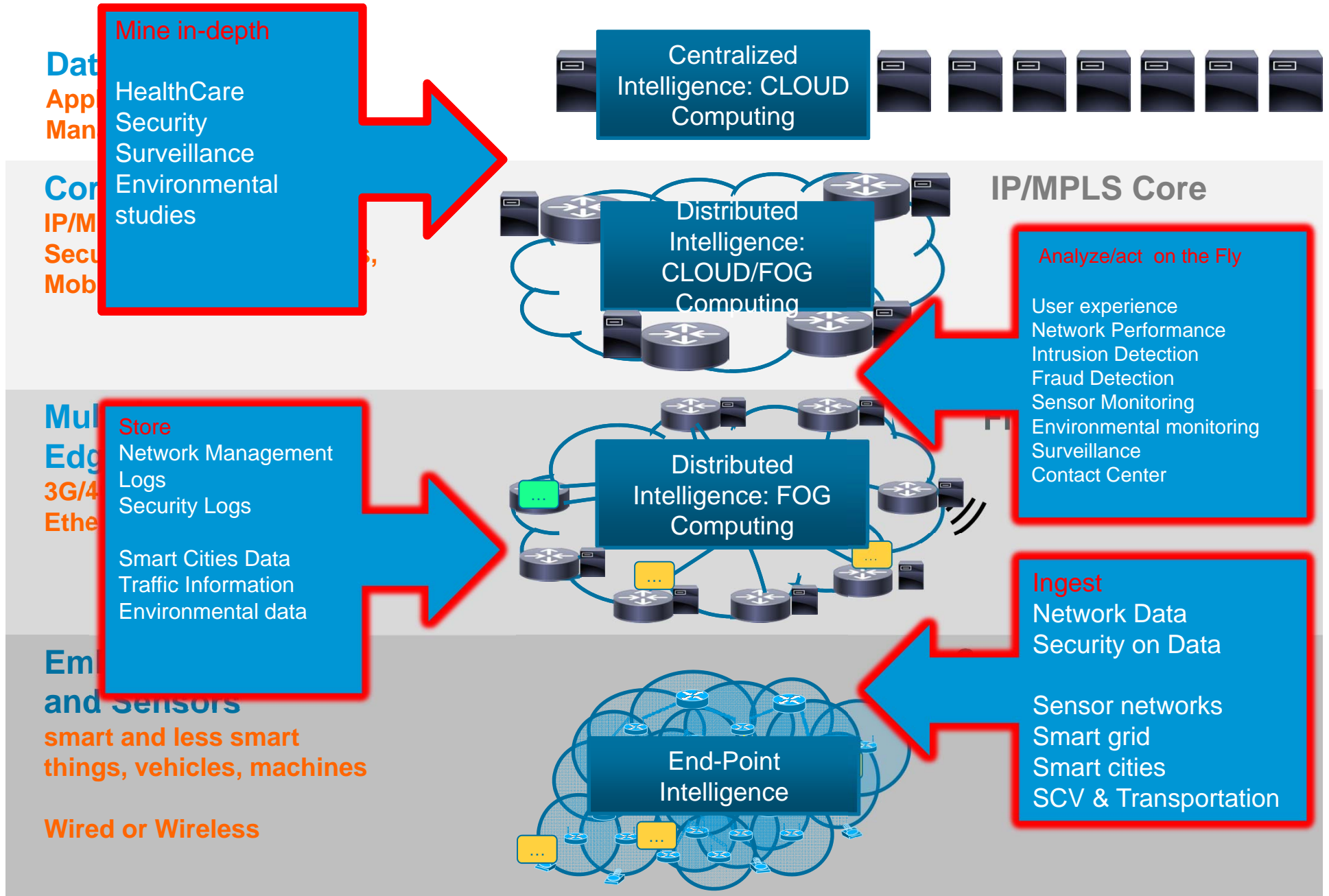
Wired or Wireless



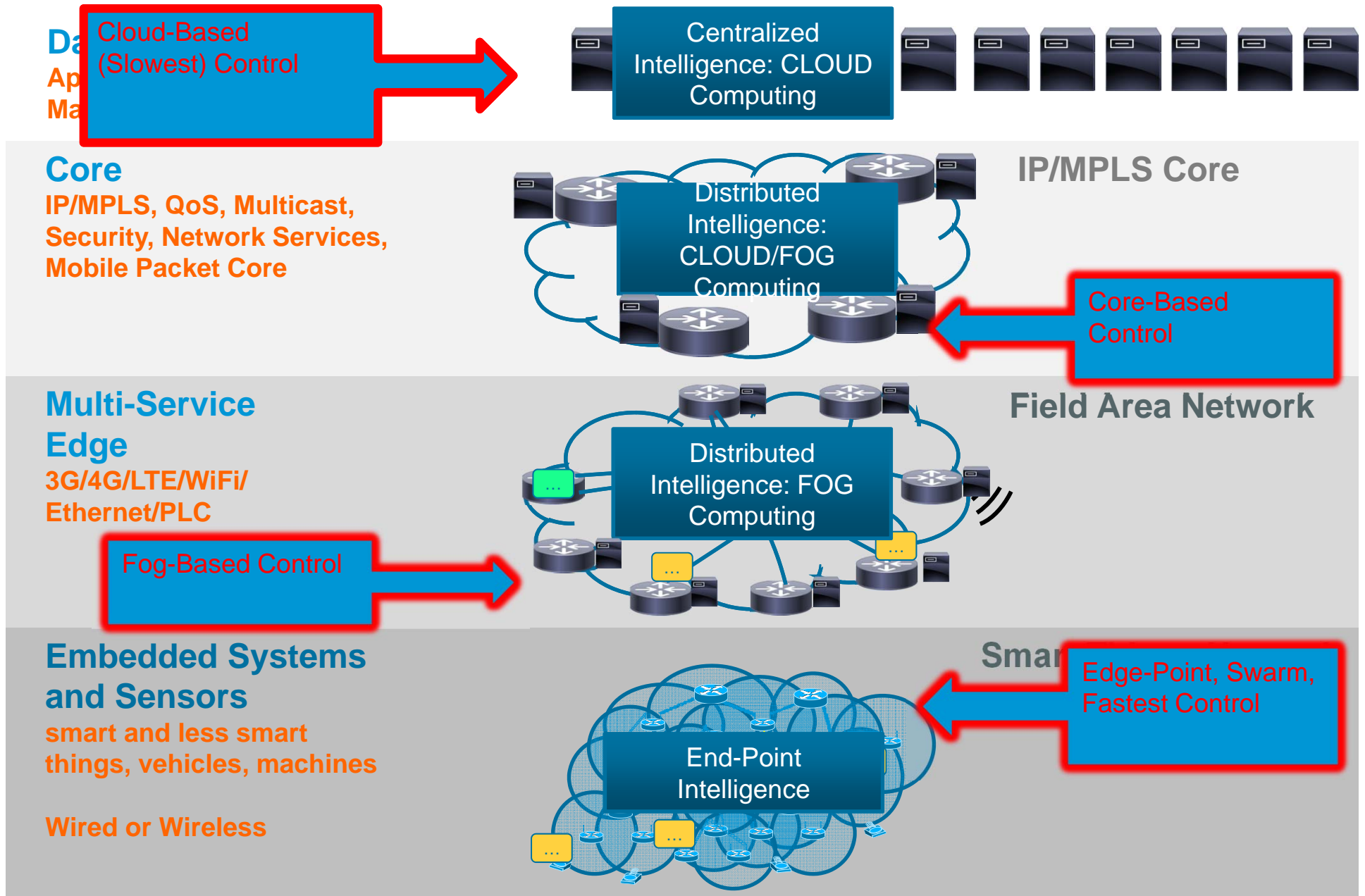
Smart Things Network

The "Swarm"

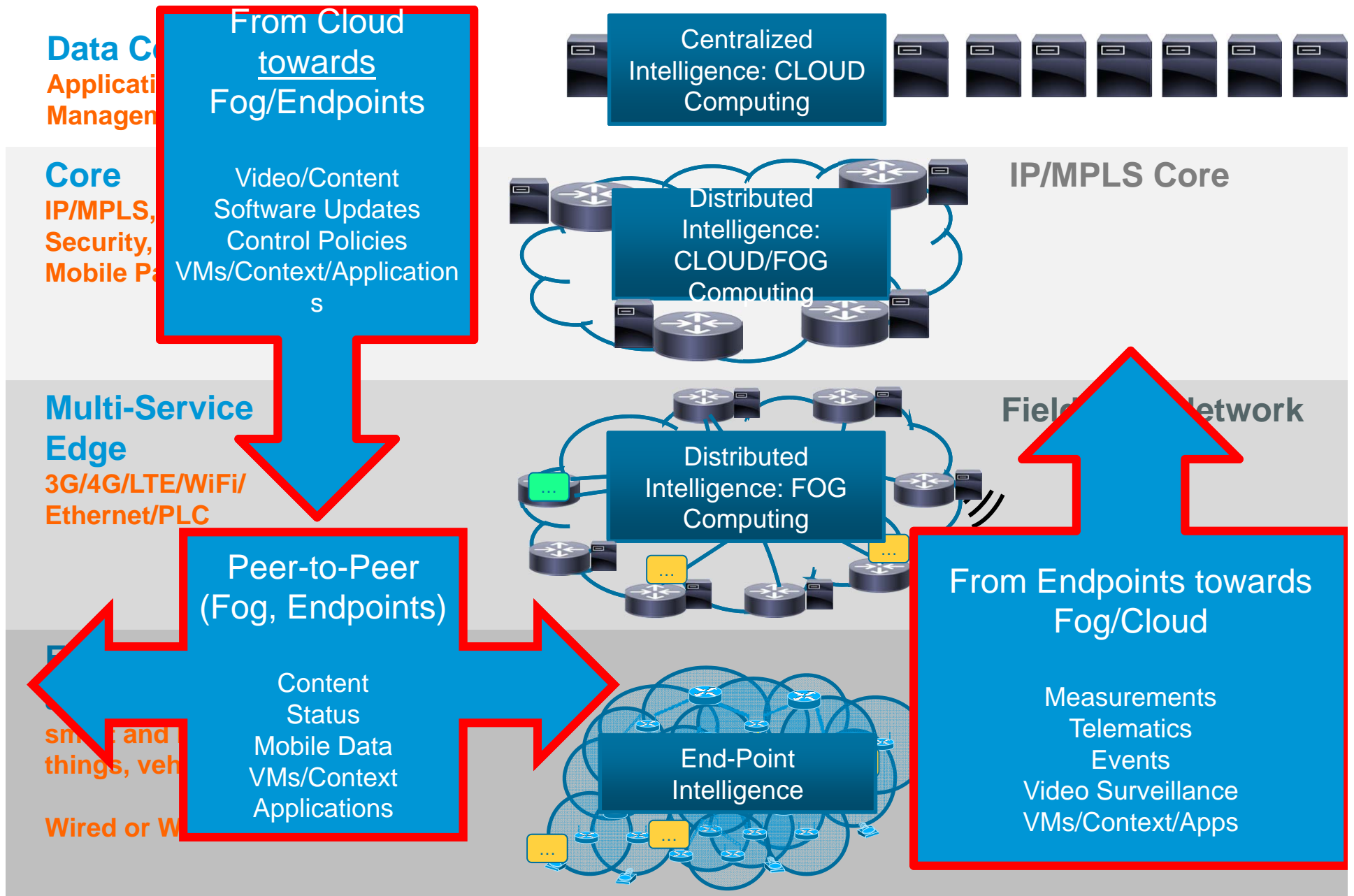
# The Role of Distributed Data Management



# The Role of Distributed Control



# The Expanded Role of Content Distribution

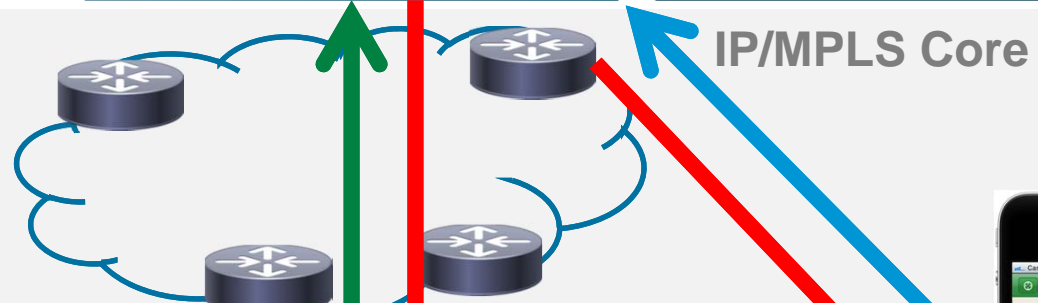


# Application Example over the “IoT Computer”: Streetline Parking Automation

**Data Center/Cloud**  
Hosting IoT analytics



**Core**  
IP/MPLS, Security,  
QoS, Multicast, Network  
Services, Mobile Packet  
Core



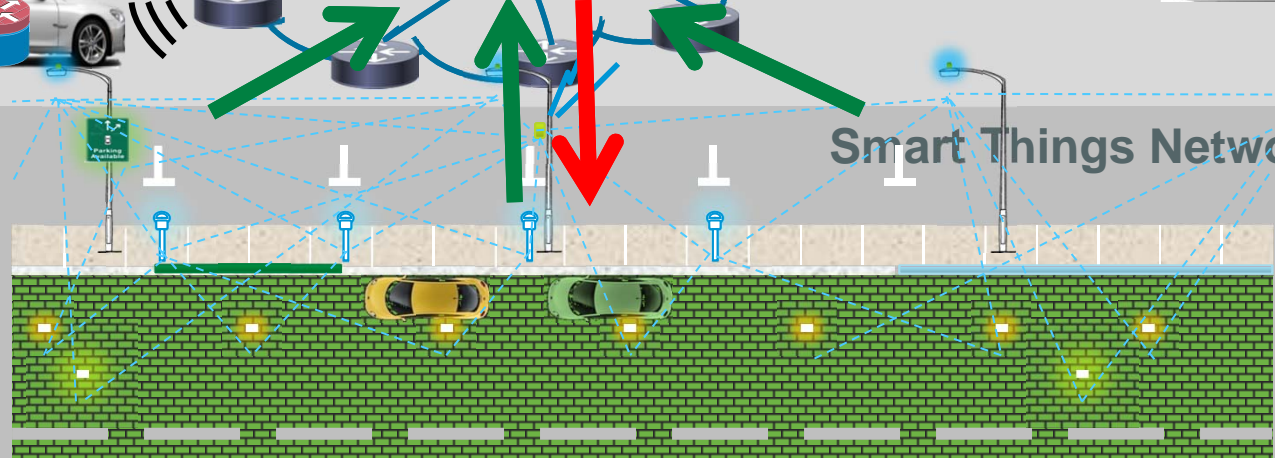
**Multi-Service  
Edge**  
3G/4G/LTE/WiFi/802.11p  
Wired



**Embedded Systems  
and Sensors**  
Low power & bandwidth,  
smart things, vehicles,  
machines

Smart Things Network

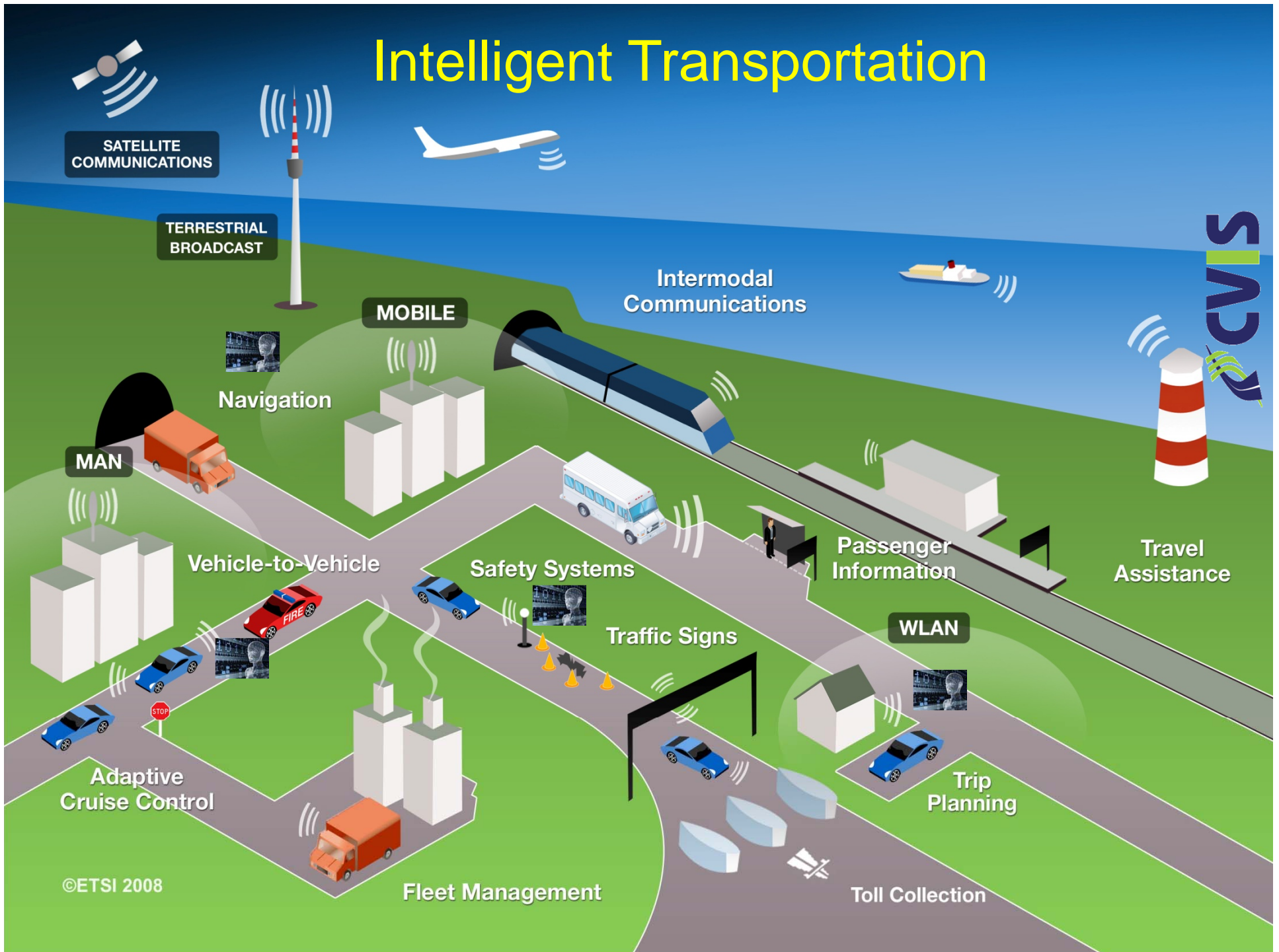
Millions



# Agenda

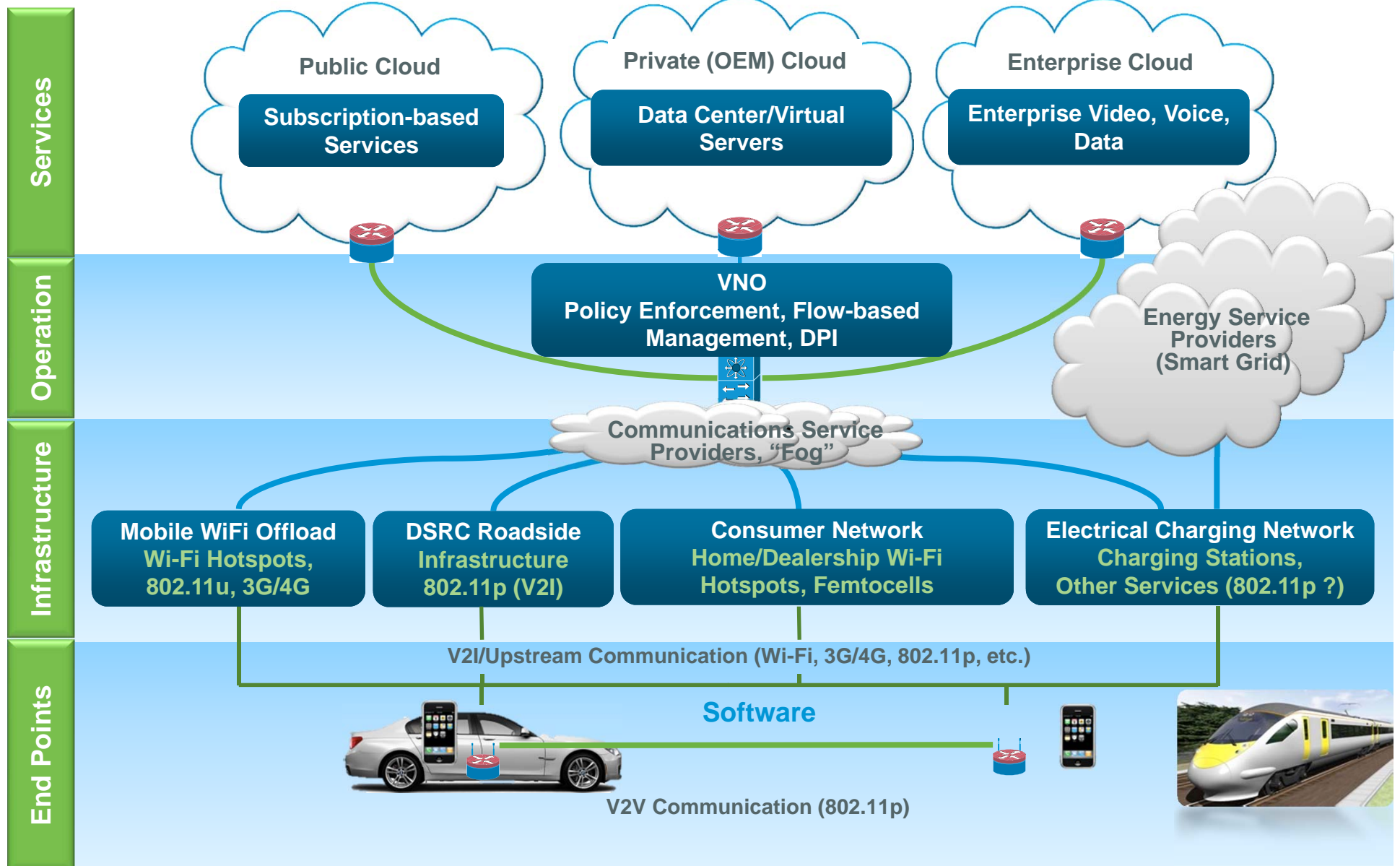
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- The Future Infrastructure for the Internet of Things
- **Intelligent Transportation and the Connected Vehicle**
- Enabling Technologies
- Conclusions

# Intelligent Transportation



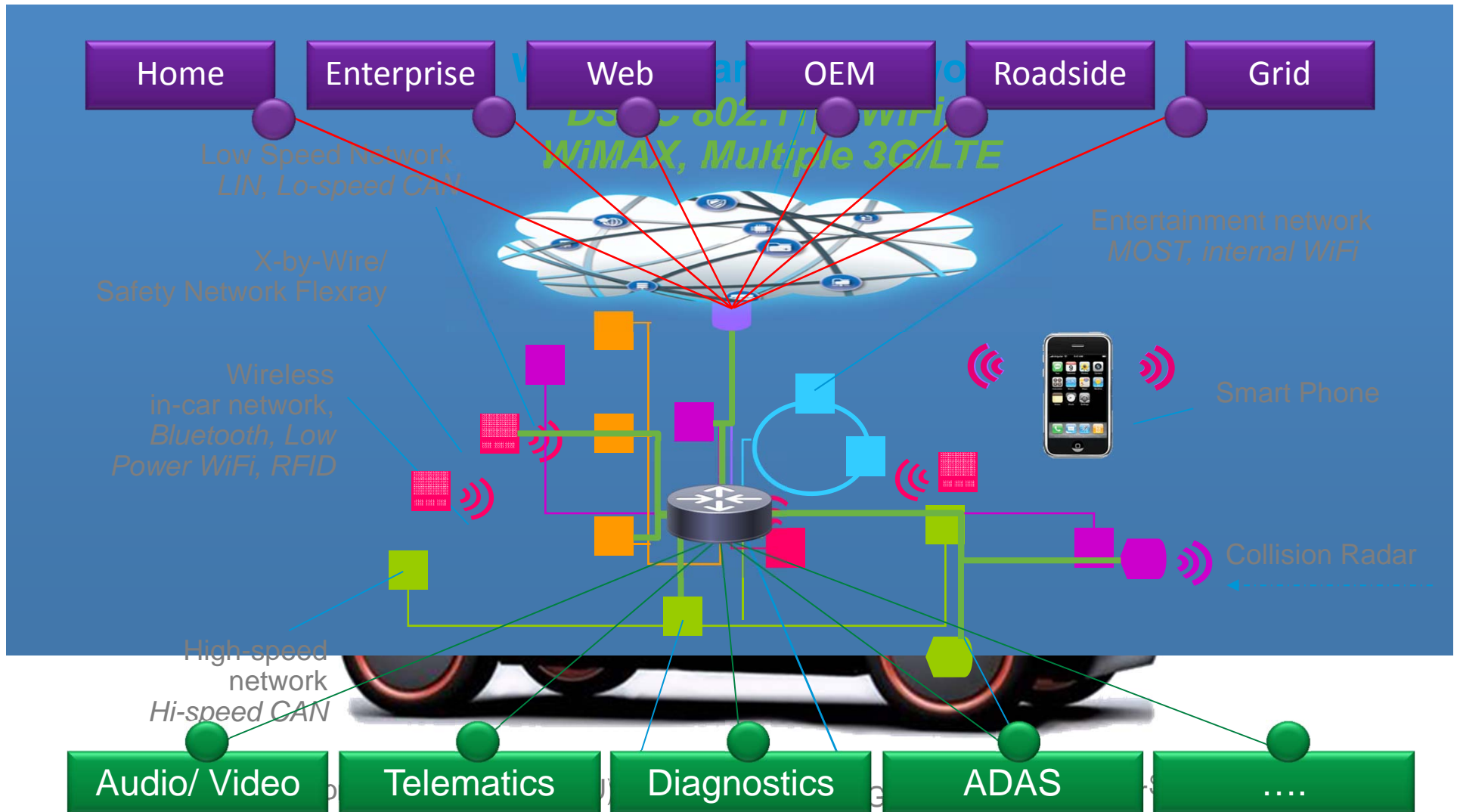
CVIS

# IoT Key Verticals (3) : Connected Vehicle and Transportation



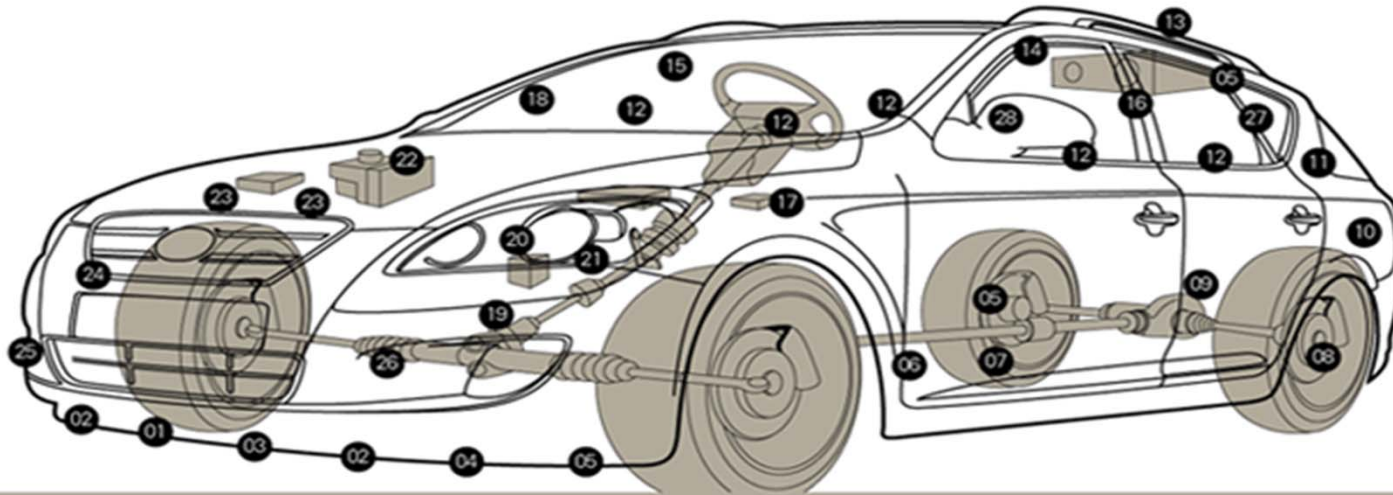


# The Connected Vehicle Evolution



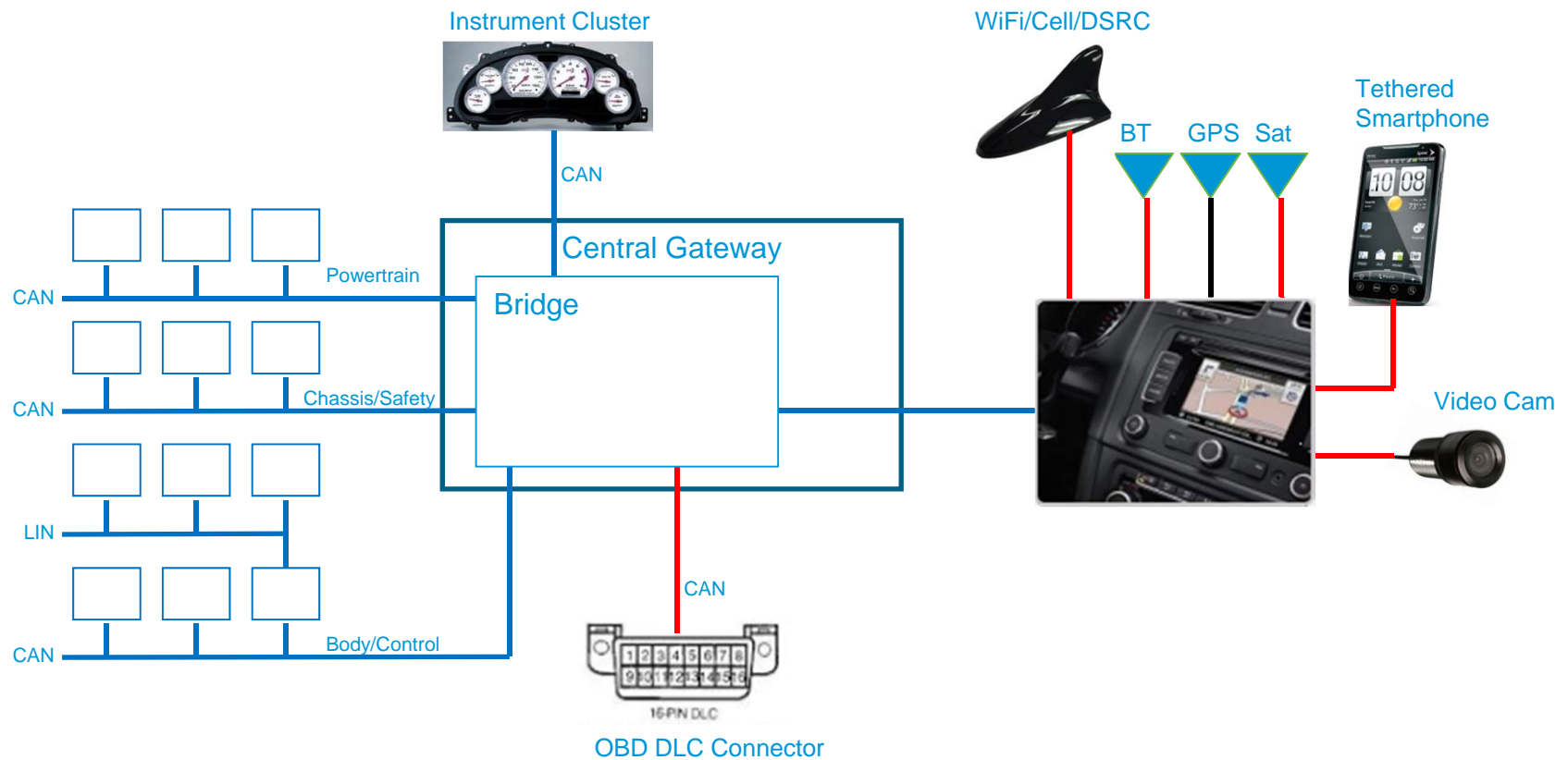
# Vehicle Internals: A Swarm of Sensors

## Advanced Safety Vehicle



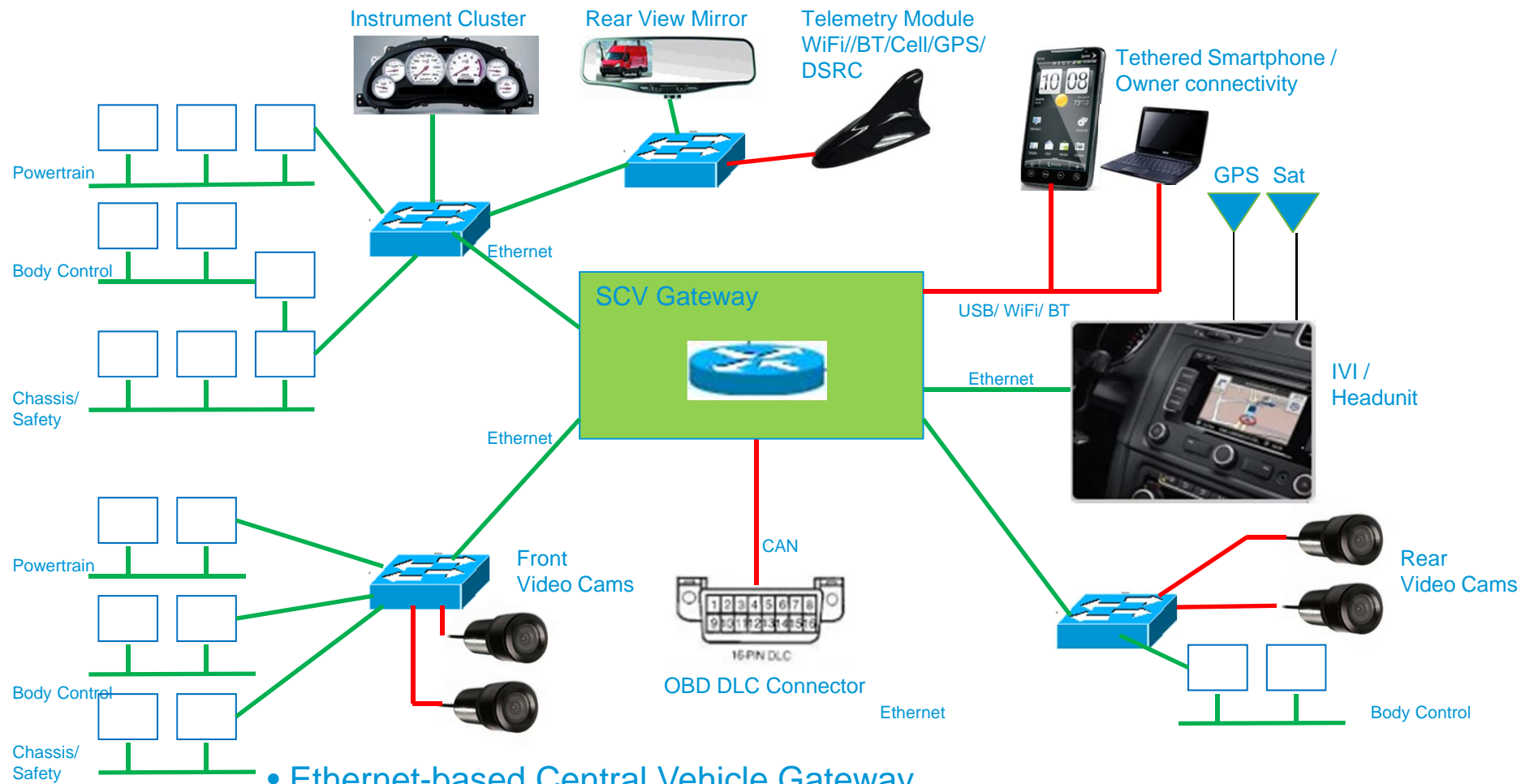
- |                                 |   |   |
|---------------------------------|---|---|
| 1. Road condition sensor        | 12. Airbag  | 22. Fire detection sensor                           |
| 2. Magnetic sensor              | 13. Road-to-Vehicle / Vehicle-to-Vehicle communication system | 23. Vehicle speed, acceleration sensor              |
| 3. Vehicle distance sensor      | 14. Rear view camera  | 24. Collision detection sensor                      |
| 4. Forward obstacle sensor      | 15. Water repelling wind shield                               | 25. Pedestrian collision injury reduction structure |
| 5. Blind spot monitoring camera | 16. Seatbelt pretensioner                                     | 26. Electronic control steering                     |
| 6. Drive recorder               | 17. Driver monitoring sensor                                  | 27. Message display system                          |
| 7. Side obstacle sensor         | 18. Headup display  | 28. Hands-free system                               |
| 8. Air pressure sensor          | 19. Steering angle sensor                                     |   |
| 9. Inside door lock/unlock      | 20. Electronic control throttle                               |   |
| 10. Rear obstacle sensor        | 21. Electronic control brake                                  |   |
| 11. GPS sensor                  |   |   |

# Traditional ECU Topology



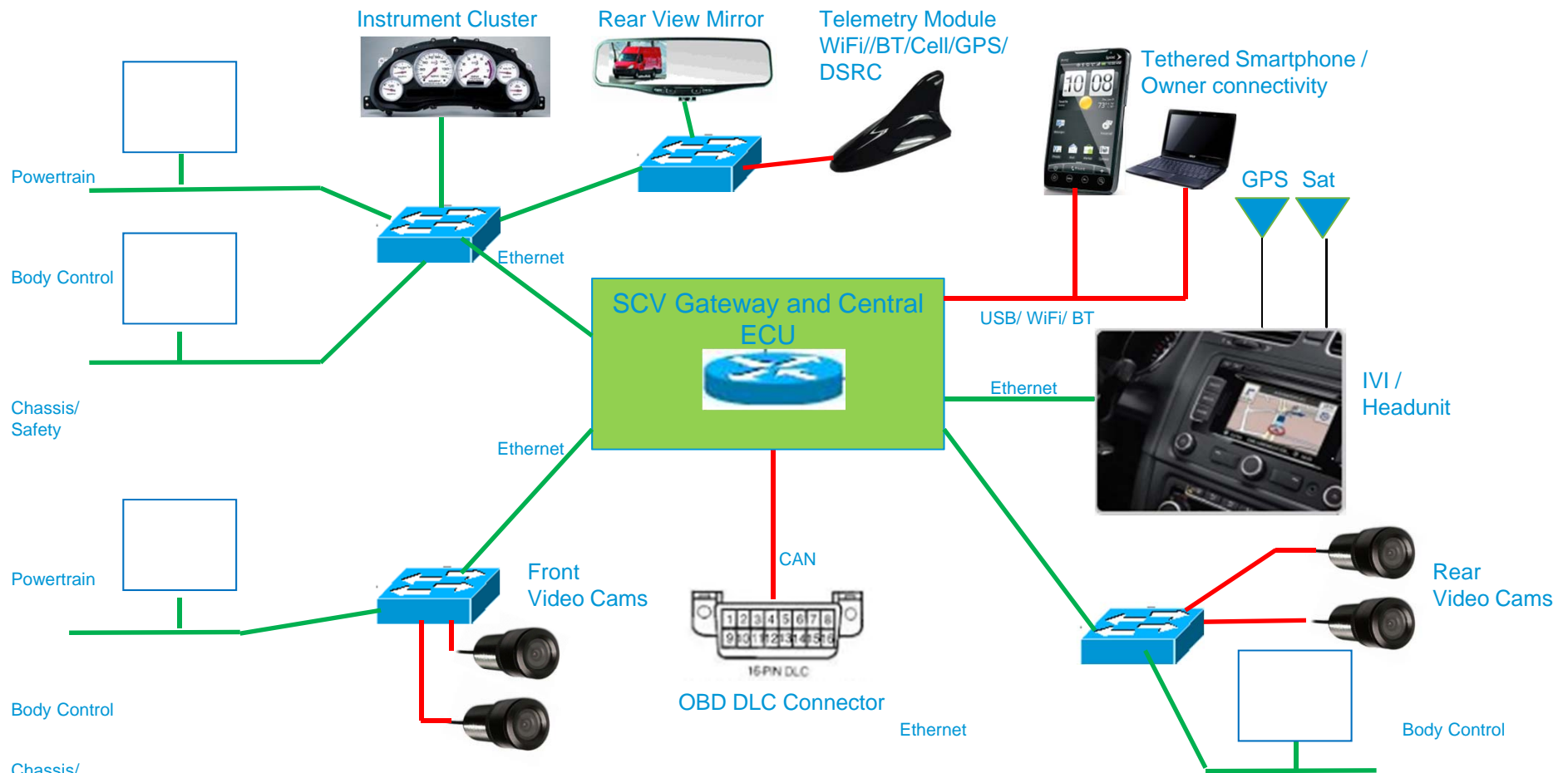
- All ECUs networked directly or indirectly via gateways / DLC Connector
- **Unsecure access** into in-vehicle network via DLC
- Network security implemented in IVI Headunit

# Integrated Future Vehicle Network



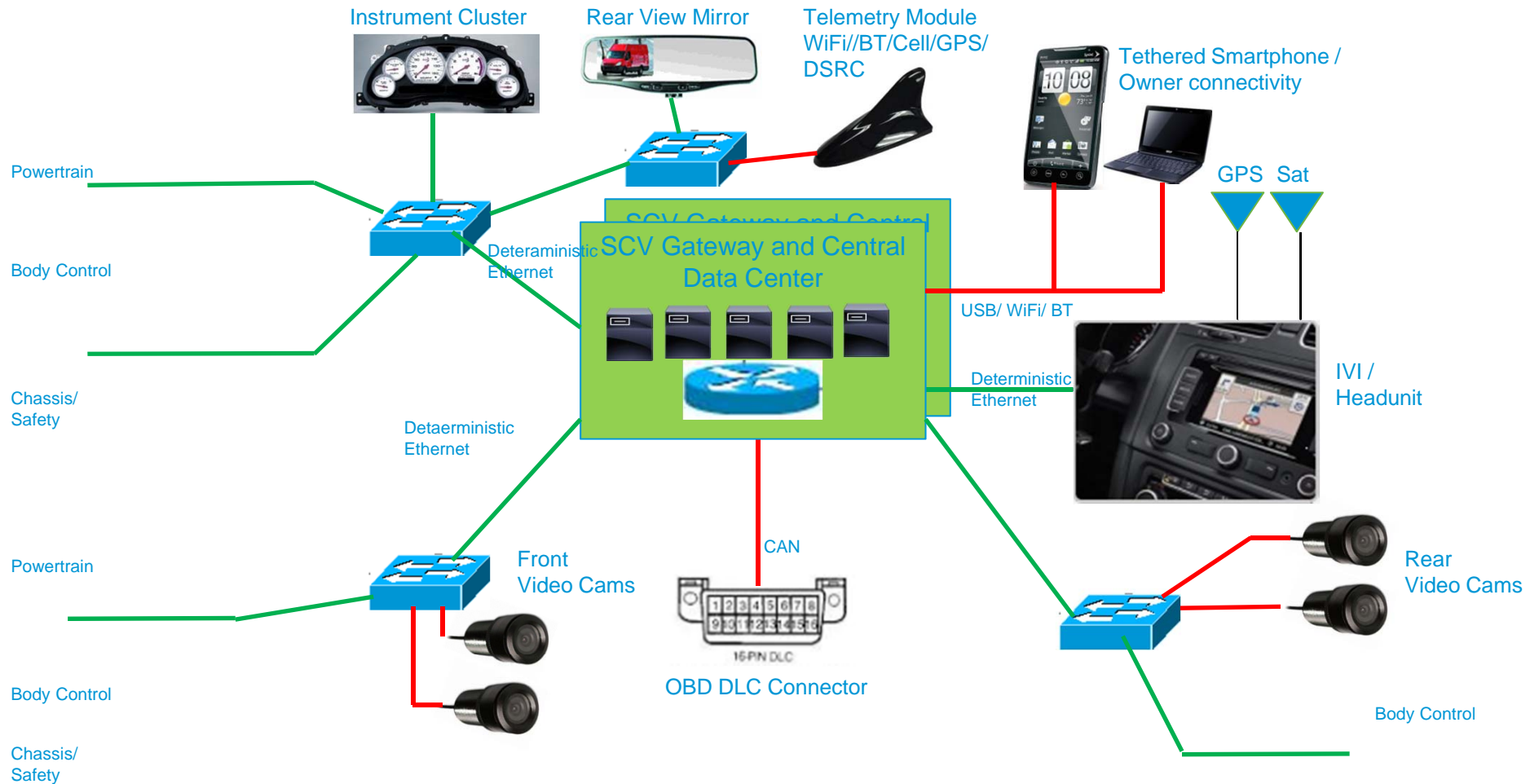
- Ethernet-based Central Vehicle Gateway
- Mini-switches/hubs aggregate ECUs/Sensors depending on location within vehicle
- Potential reduction in wiring harness density and bus splices

# Future Vehicle Network with ECU Consolidation and Virtualization



- Ethernet-based Central Vehicle Gateway
- Mini-switches/hubs aggregate ECUs/Sensors depending on location within vehicle
- Potential reduction in wiring harness density and bus splices

# Towards a Single Vehicle Data Center with Virtualized ECUs ?



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- **Enabling Technologies**
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# (A Few) Enabling Technologies

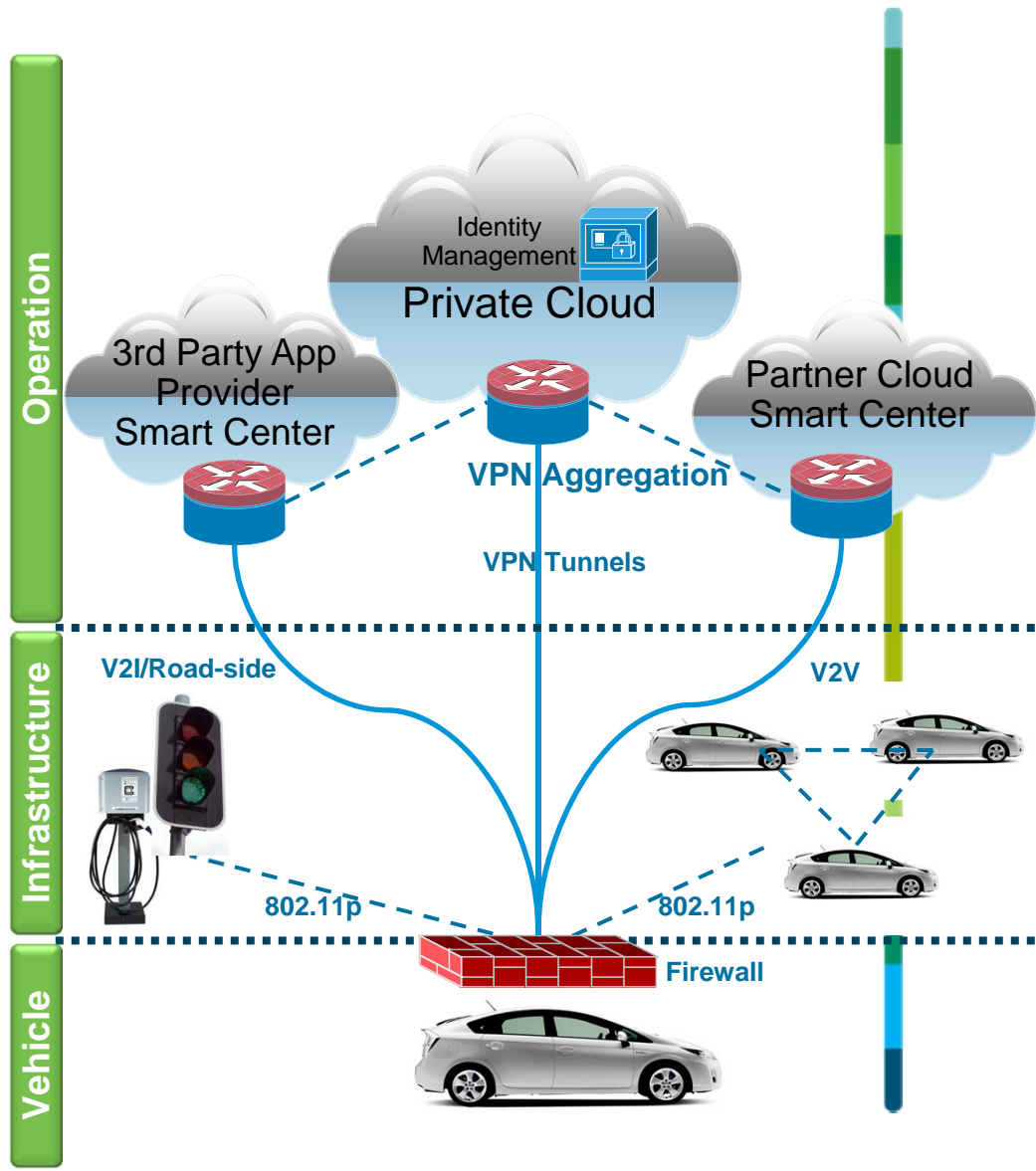
- Security
- Fog computing
- Seamless, optimized connectivity, mobility, LISP
- Ad hoc networking for mobility
- Deterministic networking (wired and wireless)
- .....



# (A Few) Enabling Technologies

- Security
- Fog computing
- Seamless, optimized connectivity, mobility, LISP
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- .....

# Secure Connectivity



Highly secure communication from car to wider network

- ✓ Encryption
- ✓ Wide range of VPN technologies
- ✓ Secure tunnels to OEM, partners, third party applications providers

Comprehensive secure In-vehicle protection

- ✓ Strong firewall
- ✓ Intrusion Prevention
- ✓ Anti-virus/malware protection

On-demand secure connectivity

- ✓ vehicle-to-vehicle, vehicle-to-infrastructure

Easy to deploy and manage

- ✓ Centralized identity & policy management
- ✓ Authentication, authorization, accounting

# (A Few) Enabling Technologies

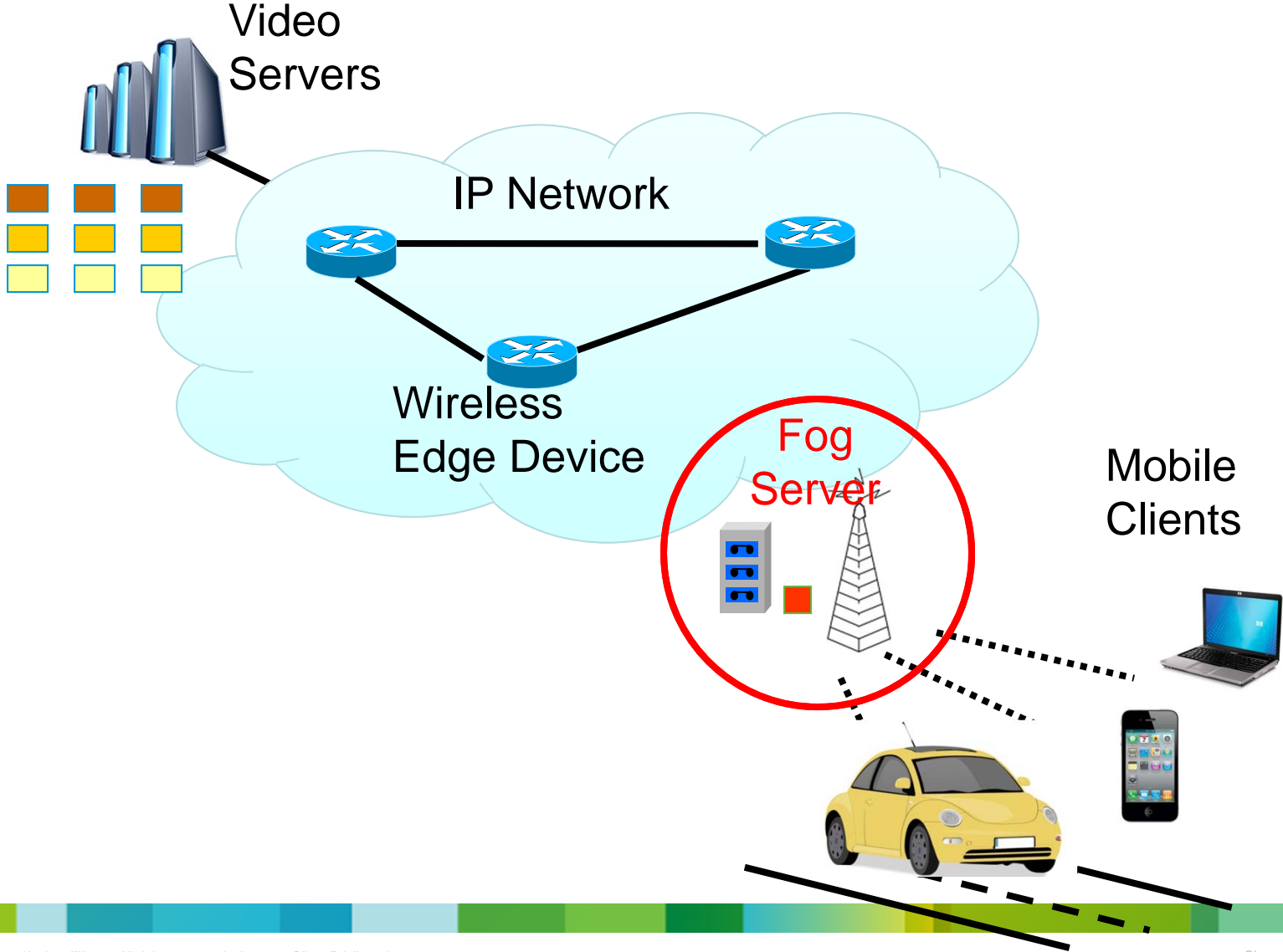
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- .....

# Fog Computing

- **Maybe just another funny name for “Edge of the Network Computing” .....**
- Systematic, highly virtualized, secure, and network-integrated computing and storage located between End-points and Clouds, supporting many of the same techniques/approaches applied to Cloud Computing:  
Virtualization, multi-tenancy, IaaS, PaaS, SaaS, automation, ....

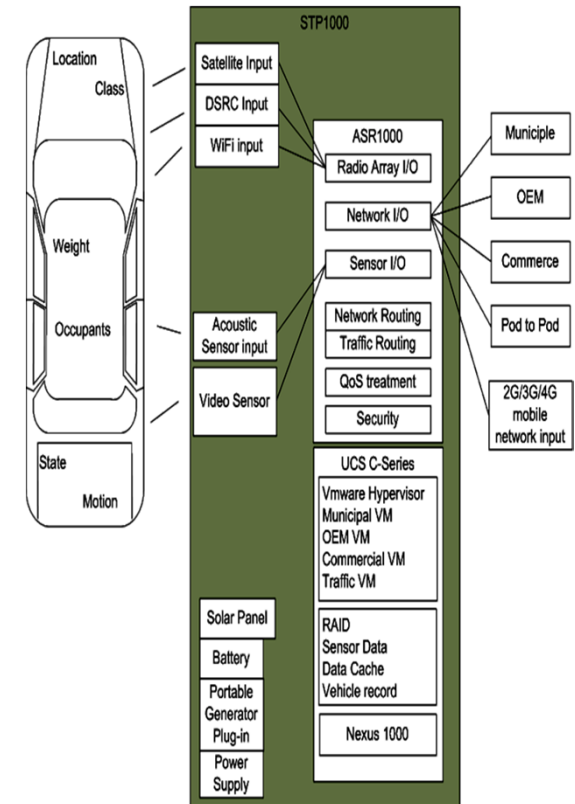


# Example Use: Fog-Based Scalable Video Streaming



# Example Use: Roadside Computing

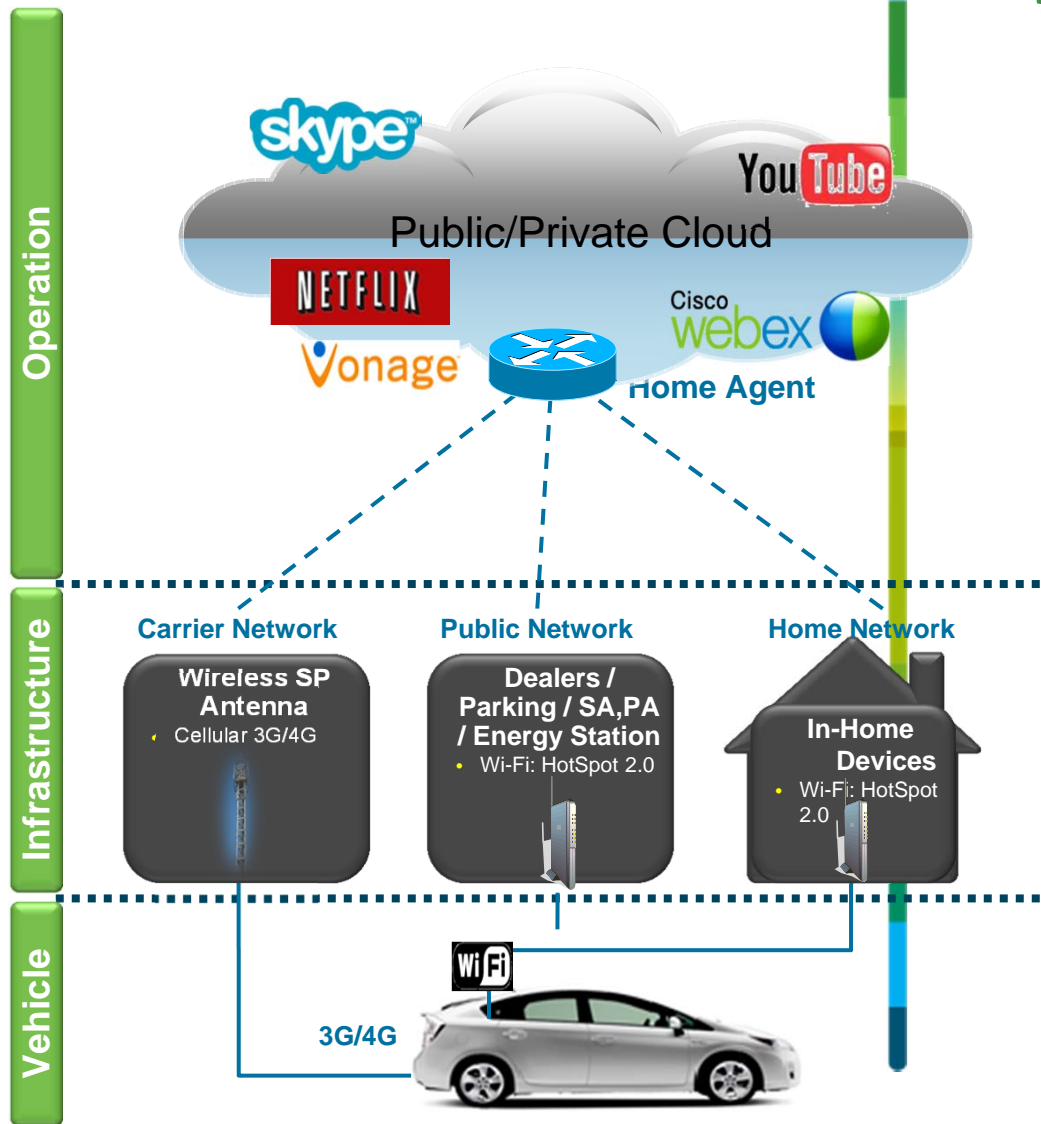
- Roadside multi-purpose equipment based on convergence of routing, computing and wireless technologies
- Distributed, multi-tenancy computing model
- Supporting multiple wireless technologies
- Located with other traffic control equipment
- Purpose - Managed Service
  - Regulate traffic (Traffic Router – cars, IP packets, same)
  - Collect tolls taxes (per transaction fee collection)
  - E-Commerce support
  - Content delivery
  - Traffic sensor management (e.g., Sensys)



# (A Few) Enabling Technologies

- Security
- Fog computing
- **Seamless, optimized connectivity, mobility, LISP**
- Ad hoc networking for mobility
- Deterministic networking (wired and wireless)
- .....

# Seamless, Optimized Connectivity, Mobility



## Multiple Wireless WAN interfaces

- ✓ 3G/4G(LTE), WiFi

## Highly Scalable Secure Mobility

- ✓ Industry leading architectures: LISP, PFR
- ✓ Mobile IPv6, NEtwork MObility (NEMO)
- ✓ Single-IP reachability

## Seamless User Experience

- ✓ Non-stop 99.99% reliable connection management
- ✓ Application-aware, flow-based connectivity
- ✓ Seamless Handover: 3G -> wifi
- ✓ Session persistency

## Optimized Communications

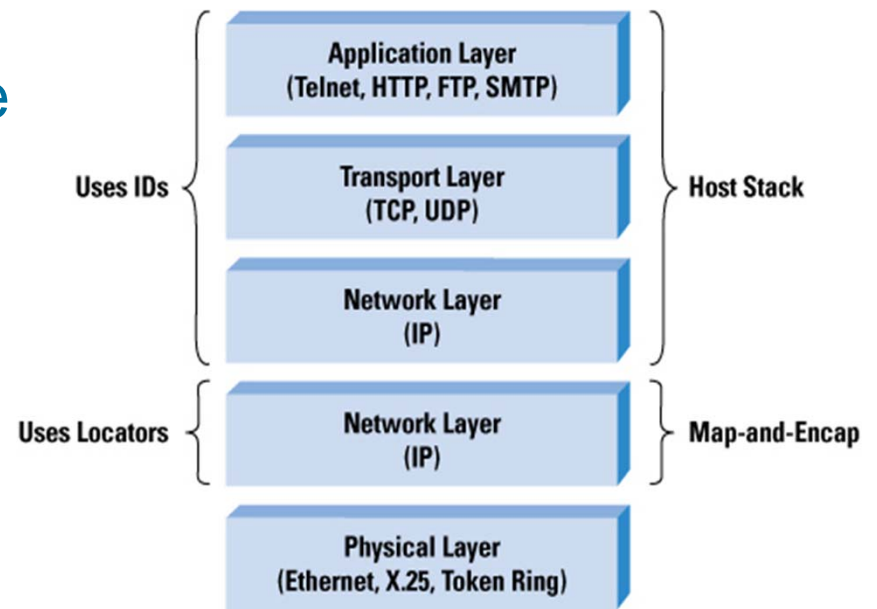
- ✓ Over 3G/4G, WiFi, ...



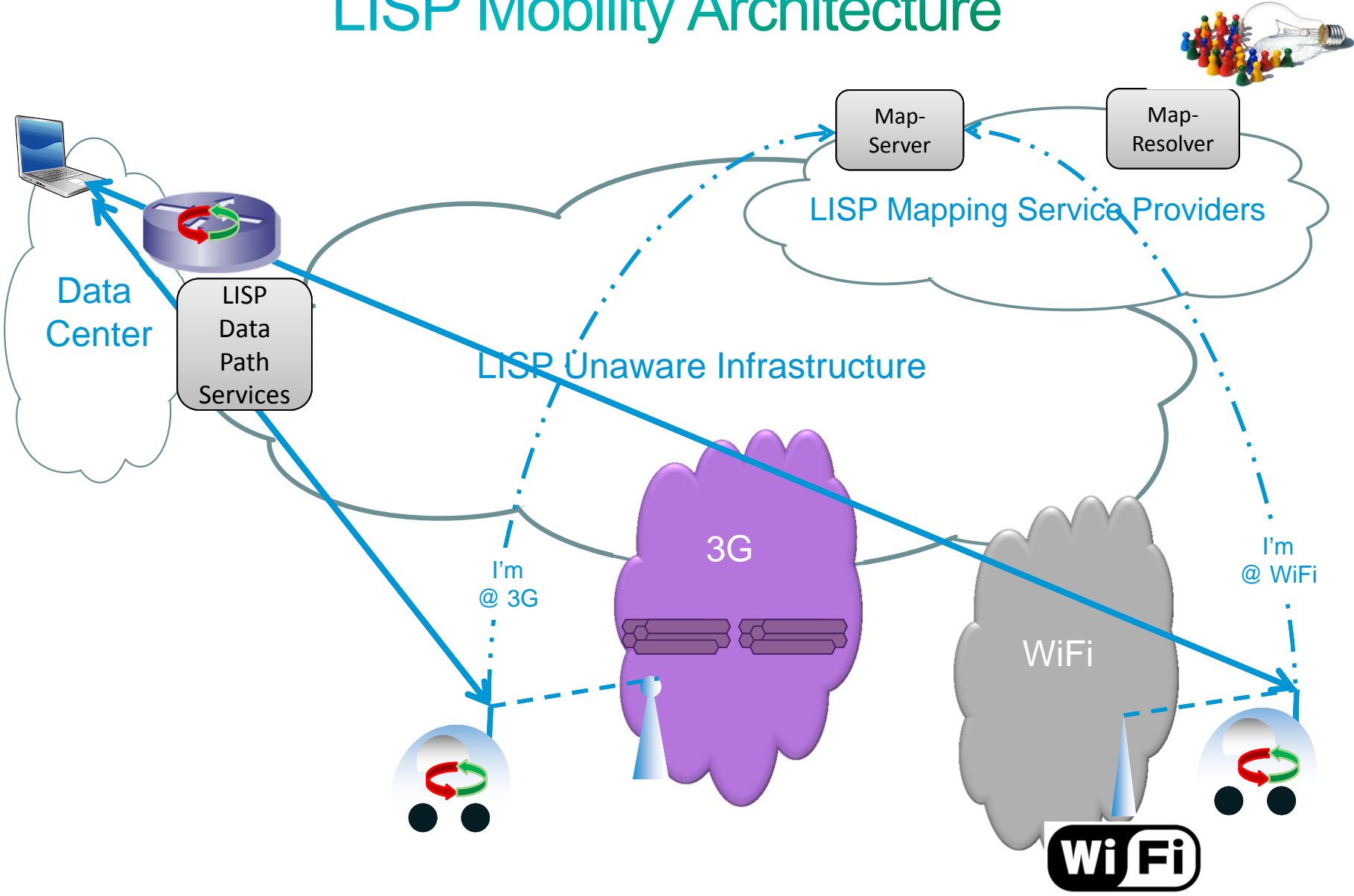
# LISP for IP Mobility



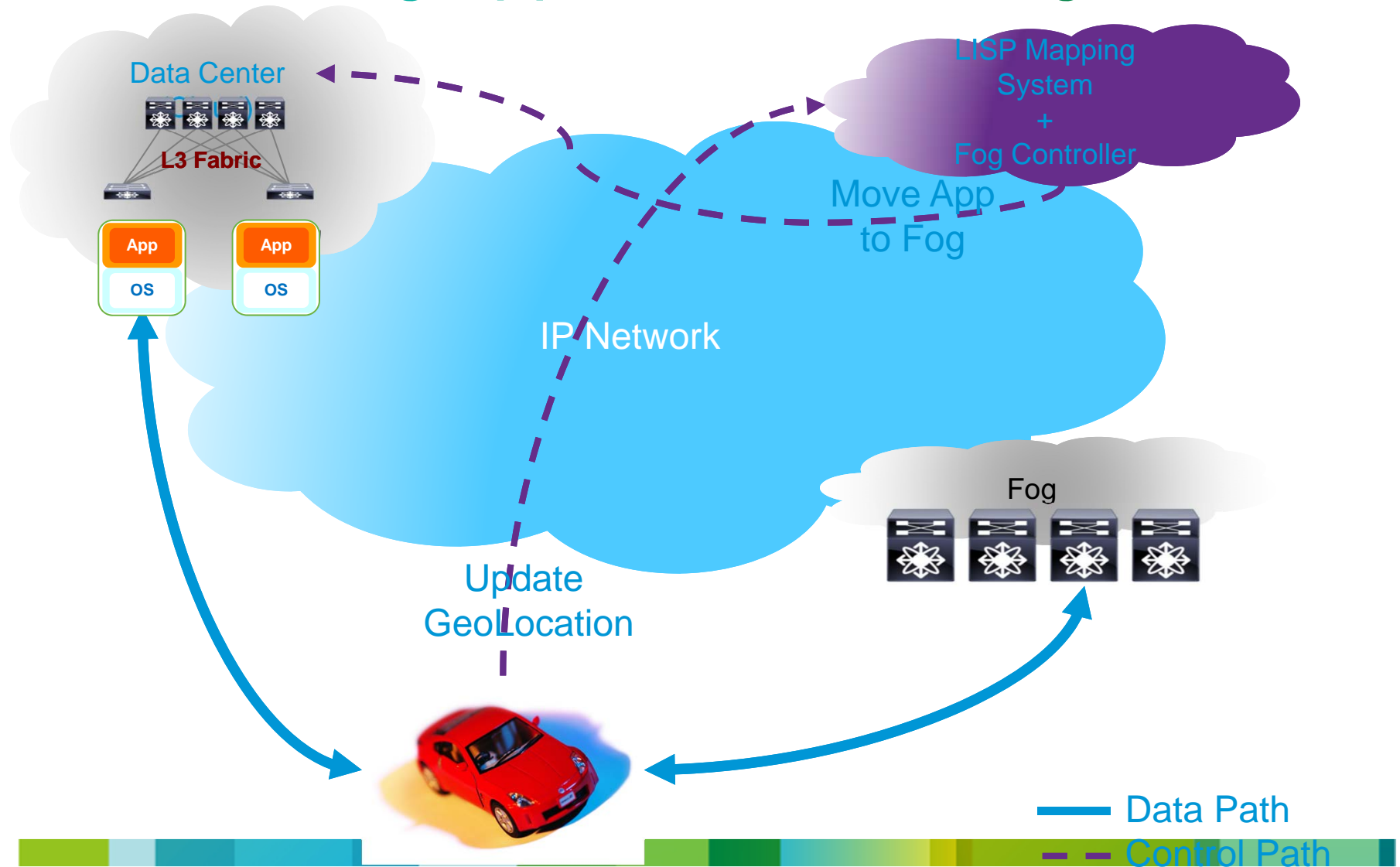
- LISP (Location Identity Separation Protocol with IP-in-IP) was originally designed as a scalable routing architecture for the Internet
- It turns out that LISP offers native support for:
  - Mobility with route optimization,
  - Multi-homing,
  - Dual Stack (IPv4, IPv6)
  - Network Mobility
- Clear separation between control suited for over-the-top deployments
  - Enabling an ecosystem of LISP Service providers to deploy global mobility applications such as the Connected Vehicle



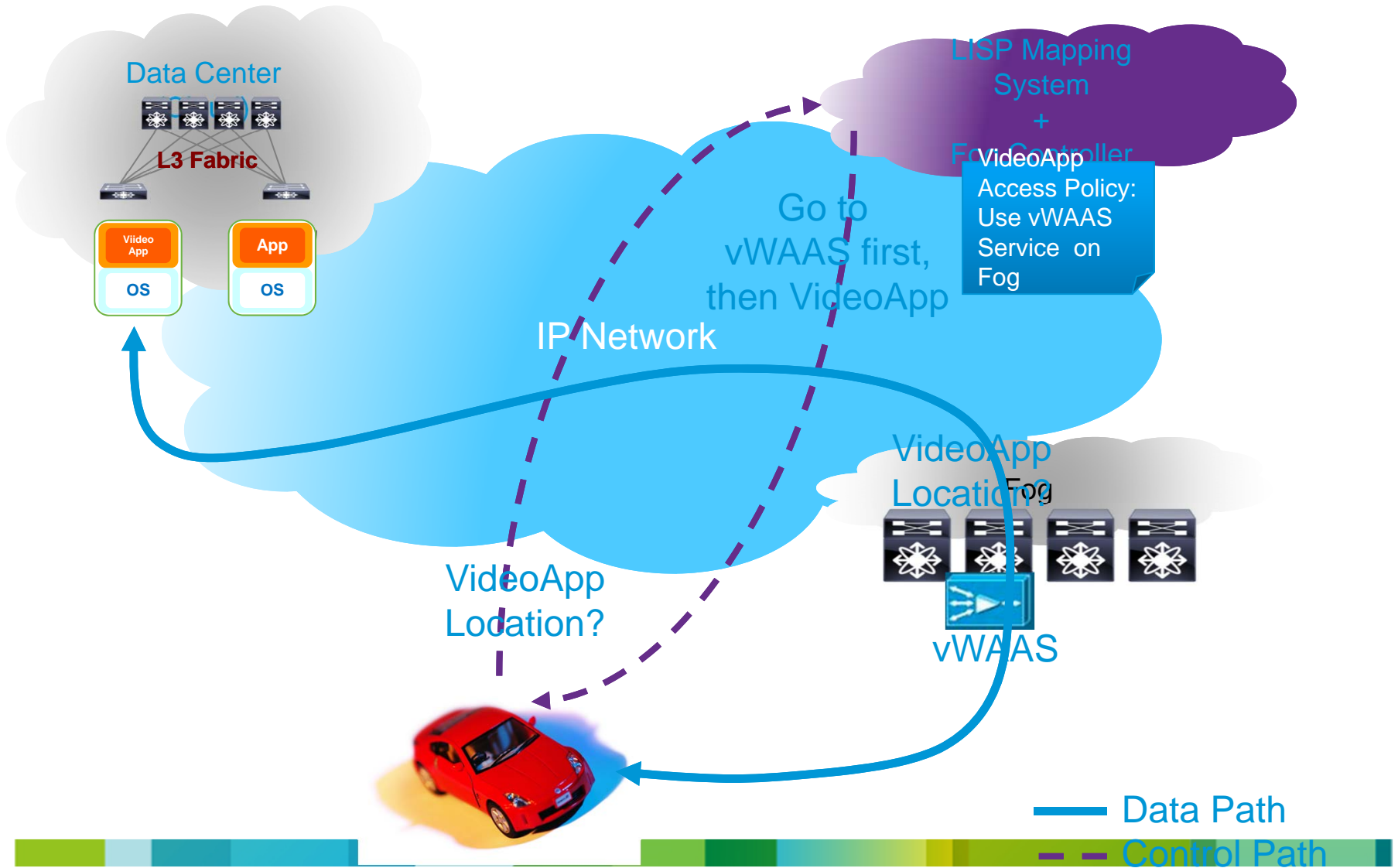
# LISP Mobility Architecture



# Cloud To Fog Application Roaming



# Fog Service Insertion



# (A Few) Enabling Technologies

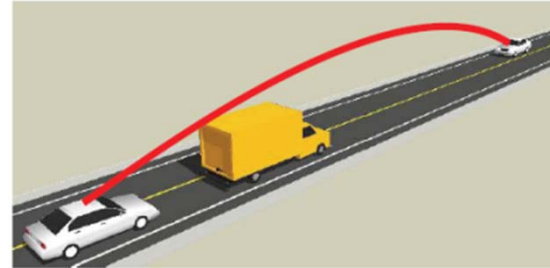
- Security
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- **Ad hoc networking for mobility**
- Deterministic networking (wired and wireless)
- .....

# Evolving and Deploying New Networking Paradigms

- **Enabling more “natural” ways of collaborating and socializing**
- **Communications for highly mobile exchanges**
- **Critical for a large set of real life applications**
- **Fundamental for transportation**
- **Enabling collaboration when not core connectivity is available**
- **Exploiting “opportunities” to communicate (Delay Tolerance)**
- **Tolerating high loss situations (Disruption Tolerance)**

# DSRC is A Key Connected Vehicle Technology

- Key technology to provide non-line-of-sight communication in next generation advanced driver assist systems



- DSRC is the global industry standard for latency critical V2V/ V2I communication
- eCall + DSRC are key triggers for broader CV deployment
- Cisco is investing in DSRC Communications
  - Joint Projects with Cohda Wireless
  - Working with University of Porto on Taxi Deployment

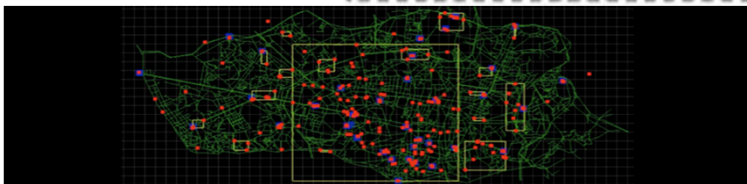
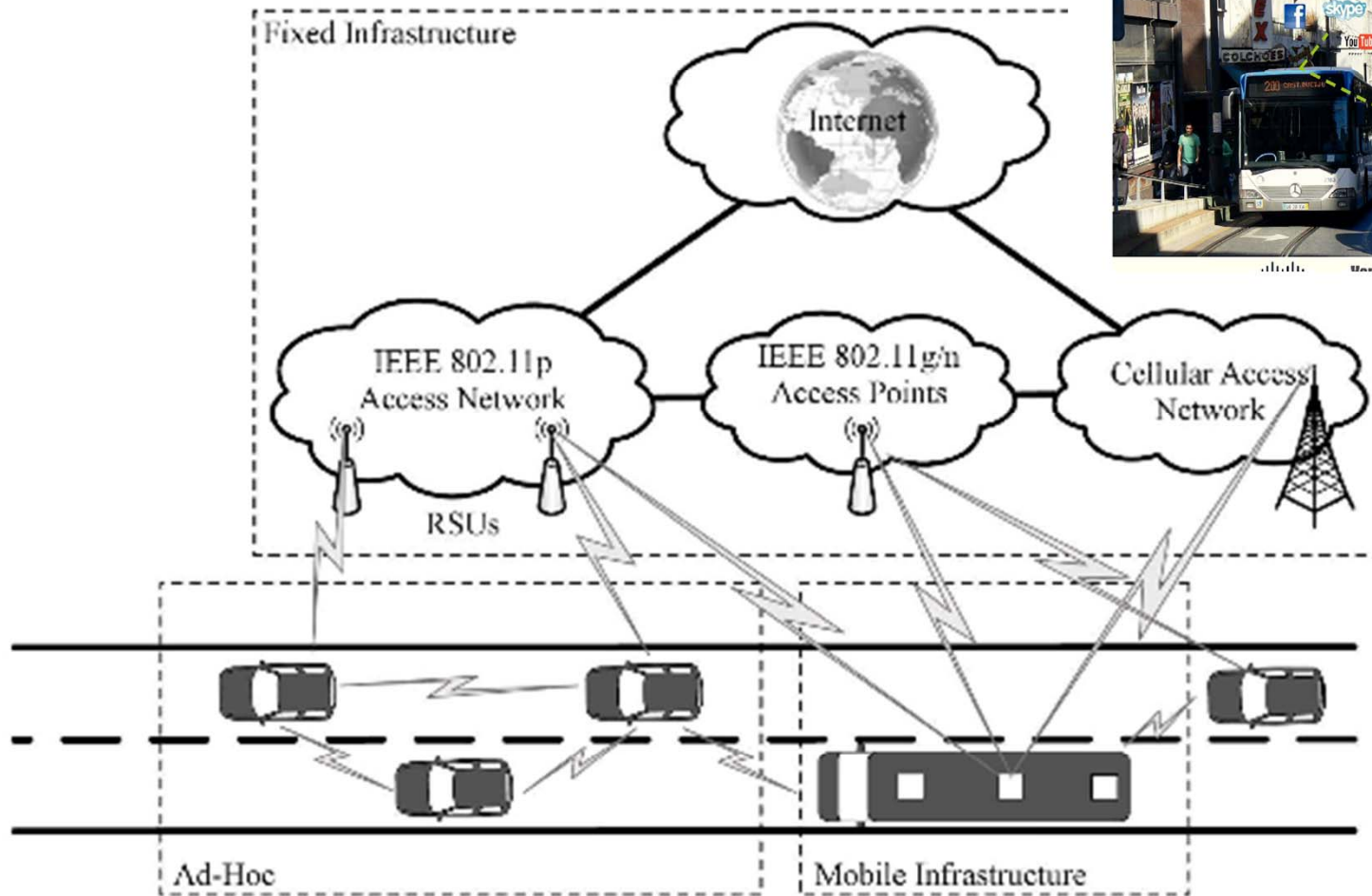
# Highway Multi-Hop Communications: Network Architecture

Need to Support Multiple Modes

- End-to-end
- Proxy-ed
- Multi-Hop
- Delay Tolerant
- Disruption Tolerant

Working with:

- U. Porto and Venian
- ITTC/UPC Barcelona
- UCLA
- WiFi Rail/McLaren

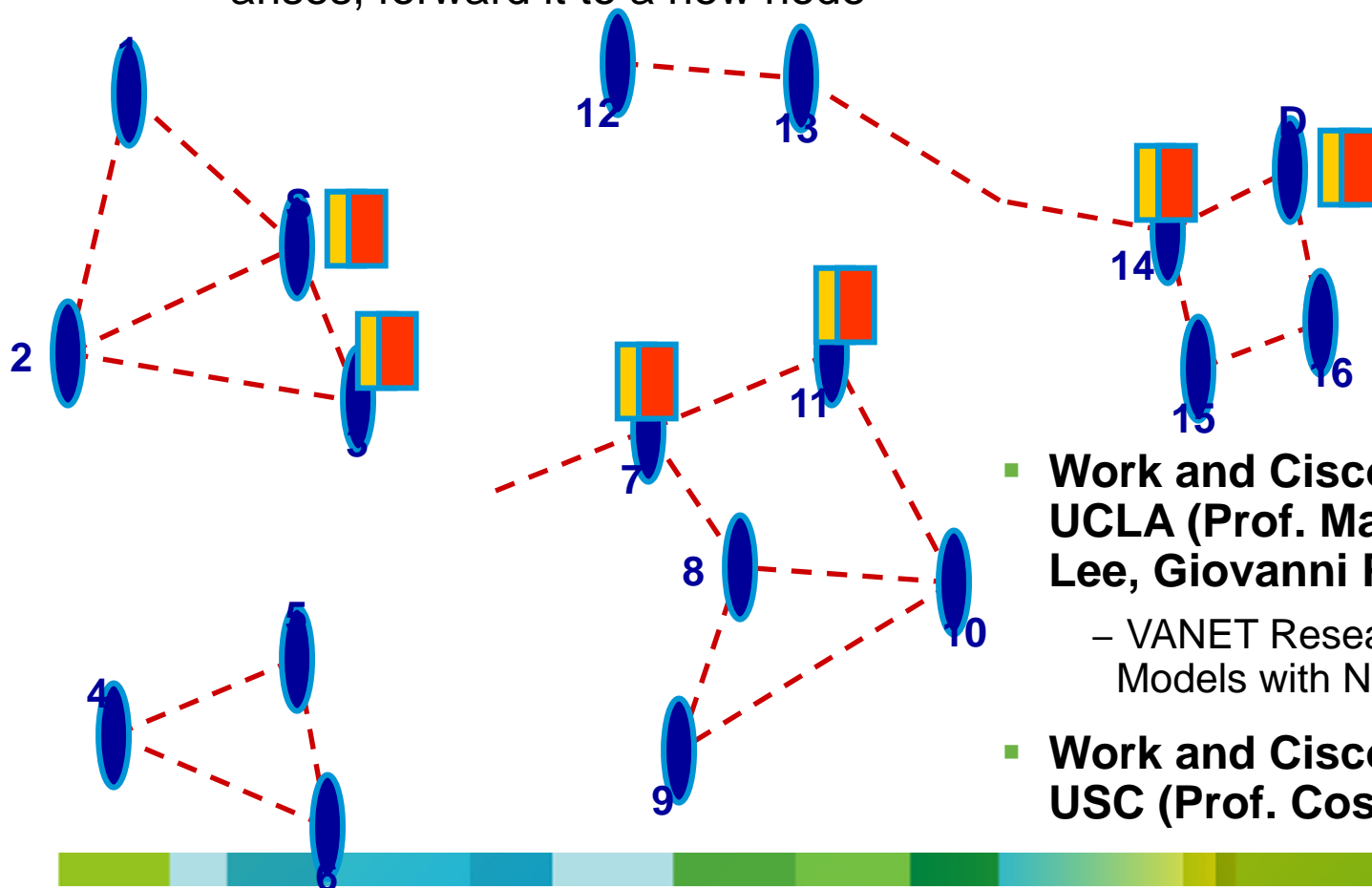




# Mobility Assisted and Hybrid Communications Models

- **Take Advantage of Node Mobility: e.g., Store-Carry-and-Forward (DTN)**

- Store a message, carry it until an appropriate communication opportunity arises, forward it to a new node



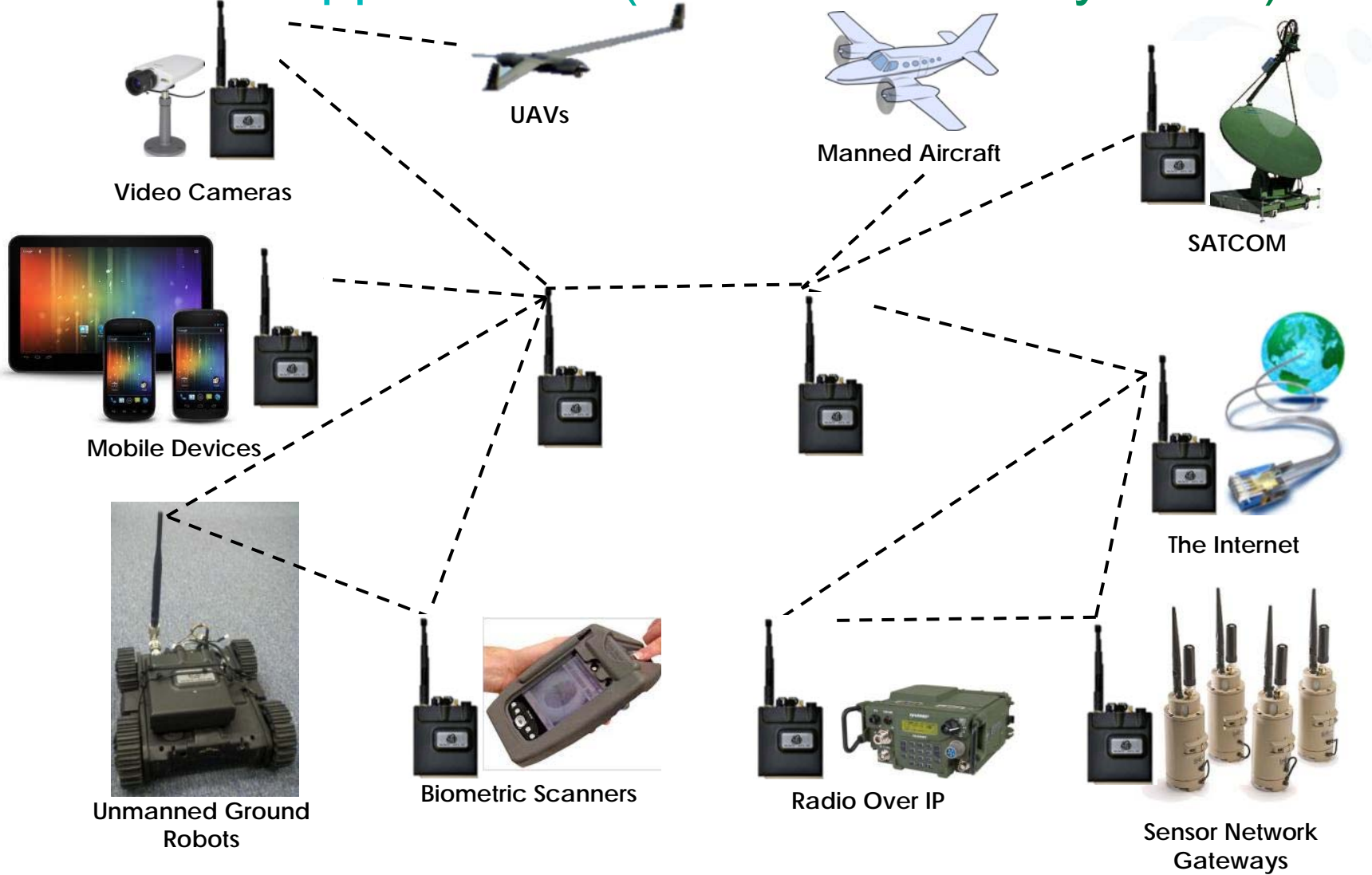
- **Work and Cisco Collaboration with UCLA (Prof. Mario Gerla, Kevin Lee, Giovanni Pau)**

- VANET Research, Hybrid Routing Models with Navigation Assistance

- **Work and Cisco Collaboration with USC (Prof. Costas Psounis)**

# Collaborative Ad Hoc Networks

## Defense Applications (see Persistent Systems)



# Collaborative Ad Hoc Networks (see Persistent Systems)

PERSISTENT SYSTEMS



## Disaster Response Network

- Large WRoIP Network with nodes in:
  - NYC & at FDNY Fire Department Operation Center in Brooklyn
  - State of Connecticut Governors Office and Emergency Operations Center
    - Multiple mobile vehicle nodes with 4G Backhaul
  - Boston at USCG Stations and Logan International Airport
    - Backhaul via 4G



# (A Few) Enabling Technologies

- Security
- Fog computing
- Seamless, optimized connectivity, mobility, LISP
- Ad hoc networking for mobility
- **Deterministic networking (wired and wireless)**
- .....

# Deterministic Networking: Motivation and Key Elements

- Required in Industrial Automation, System Control, Automotive, Smart Grid, Robotics, Building Automation, etc.
- Key Elements: (Both wired and wireless)
  - Network Ingress shaping
  - Network synchronization
  - Timely transmission
  - Centralized scheduling  
(NP-complete optimization problem)
- Wired: Time Triggered Ethernet
- Wireless: Over 802.15.4 for low power low rate (4Hz), over WIFI (802.11ac) for higher rate (100Hz)

**Cleveland, Columbus & Cincinnati R. R.**

**SPECIAL TIME SCHEDULE**

FOR THE TRAIN CONVEYING THE  
**REMAINS OF ABRAHAM LINCOLN, LATE PRESIDENT OF THE U. S., AND ESCORT**  
FROM WASHINGTON, D. C., TO SPRINGFIELD, ILL.

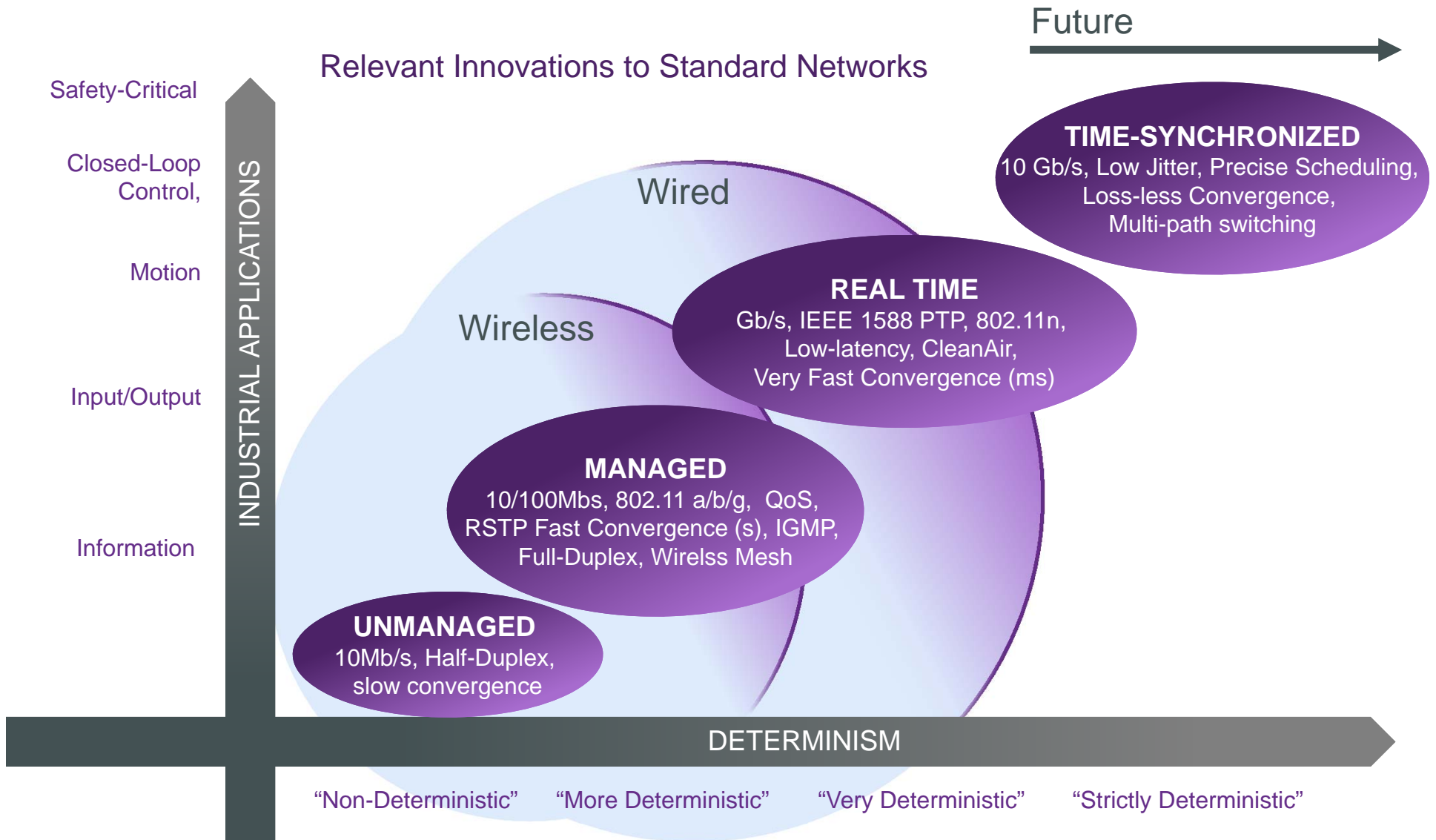
**Cleveland to Columbus, Saturday, April 29th, 1865.**

Leave Cleveland	12.00	Midnight.
Berea	12.43	A. M.
Olmsted	12.51	"
Columbia	1.02	"
Grafton	1.33	"
La Grange	1.37	"
Wellington	2.00	"
Rochester	2.17	"
New London	2.36	"
Greenwich	2.59	"
Shiloh	3.19	"
Shelby	3.39	"
Crestline	4.07	"
Galion	4.23	"
Iberia	4.41	"
Gilead	5.05	"
Cardington	5.20	"
Ashley	5.43	"
Eden	5.55	"
Berlin	6.19	"
Lewis Centre	6.32	"
Orange	6.57	"
Worthington	6.56	"
Arrive Columbus	7.30	A. M.

This Train will have exclusive right to the Road against all other Trains & First Locomotive will be run ten minutes in advance of the above schedule time.

E. S. FLINT, Superintendent.

# Further Evolution of "Ethernet" Towards Determinism

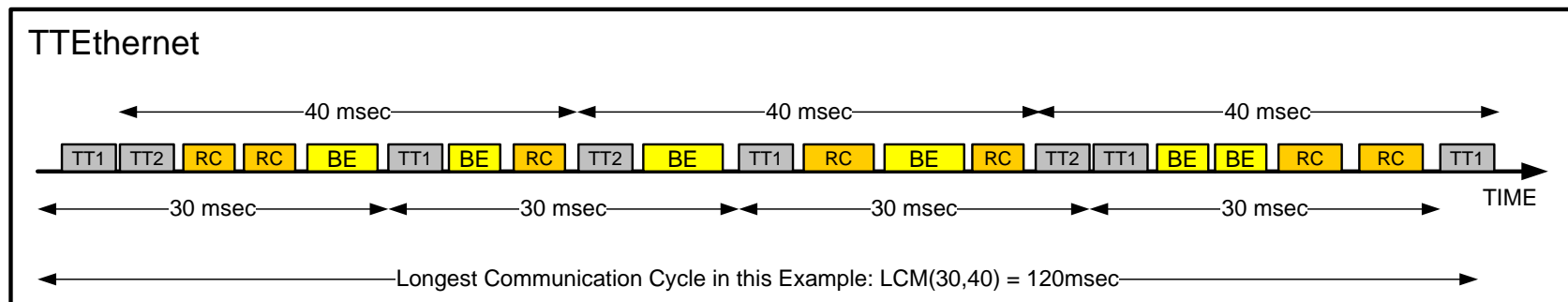


# Deterministic Ethernet: Time Triggered Ethernet

## Time-triggered service for Ethernet

- Emulates circuit-switching over Ethernet (TDMoE, Pseudowire) in complex multi-hop networks
- Makes Ethernet deterministic, lossless and hard real time (with fixed latency)
- Allows synchronous communication in parallel with IEEE DCB services (complements IEEE DCB and enhances data center networking)
- Enhances virtualization and resource sharing in distributed systems

Synchronous hard real-time communication (TDMoE)  
(min.& constant latency, jitter 1µs)



Source: TTEch

# Deterministic IoT/loE at Layer 3: 6TSCH (Sixtus)

- Value Prop
  - IPv6 for mission-critical Applications
    - Industrial, Avionics, Telematics, spatial C&C
  - Cisco business in wired and wireless backbone
  - Converged Campus / Enterprise (adding loE)
- Objectives
  - IETF standards
  - Trigger open source implementation
  - Build Ecosystem
- Status: IETF WG creation starting
- ¼ people initially



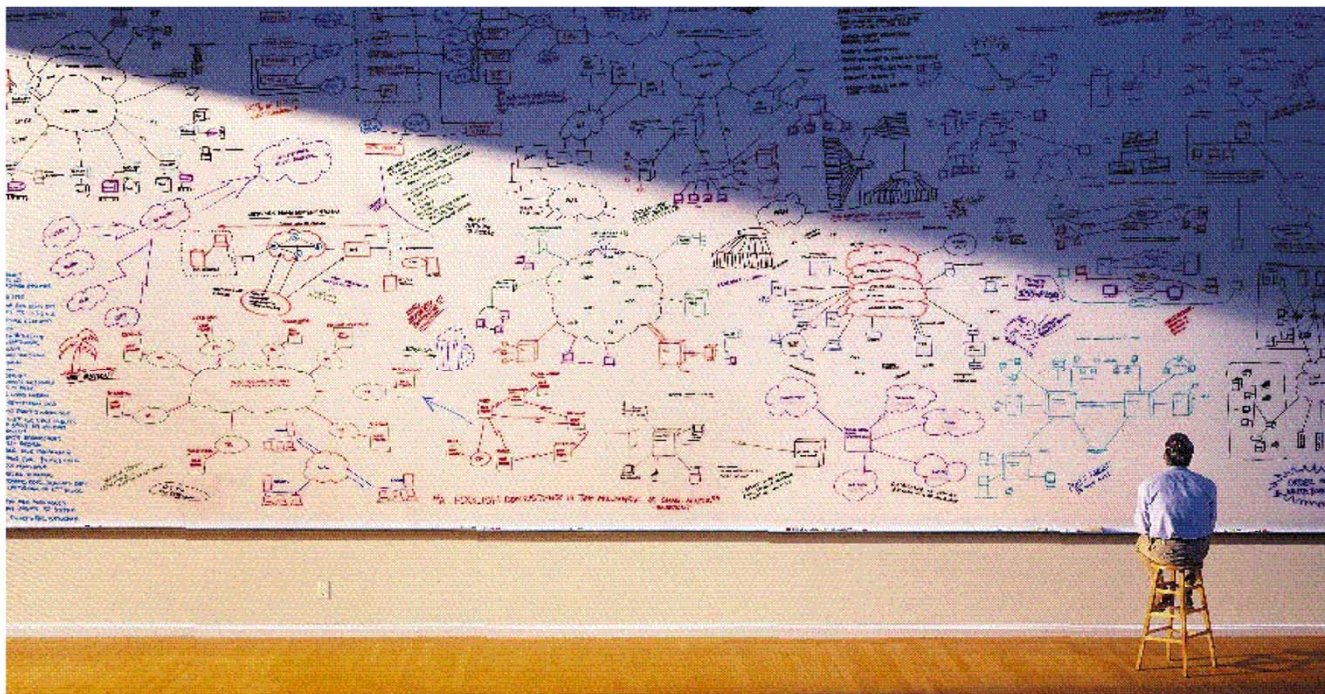


# Agenda

- An Introduction to the Internet of Things
- The Future Infrastructure and the Huge Role for Wireless Communications!!
- Enabling Technologies and Relevant Case Studies
- **Conclusions**

# Conclusions

- A time of exciting developments in Networking and beyond
- We need strong Research Collaborations: WE NEED YOU!!!
- Profound impact at human, social, and environmental levels
- Virtuous cycle between new applications, services, and innovative platforms



# Research Collaborations are Critical for the Future

## Three Dimensions



- More Traditional Industry-University Focused Research Initiatives



- Multi-Way Research Partnerships are Key
  - Networking Industry-Car OEMs-Universities
  - Networking Industry-Silicon Providers-Service Providers
  - Content Providers-OEMs
  - University-Industry (e.g., GSRC, Clean Slate, RadLab)



- Government Involvement

NSF – GENI

DOT - DOE

Leveraging of Defense Technologies



Thank you.

