Keynote

IEEE WAVE 2009 Conference

21 December 2009, Shanghai, CHINA

Research Challenges in Intelligent Transportation Networks

C. K. Toh, FIEEE
CTA, ALICO Systems Inc., USA
CTO, Acroem Inc.,

Honorary Professor, HKU
Email: ckt@eee.hku.hk
http://monet.knu.ac.kr/~cktoh

Audi INFINITI Mercedes-Benz HYUNDAI BMW LINCOLN

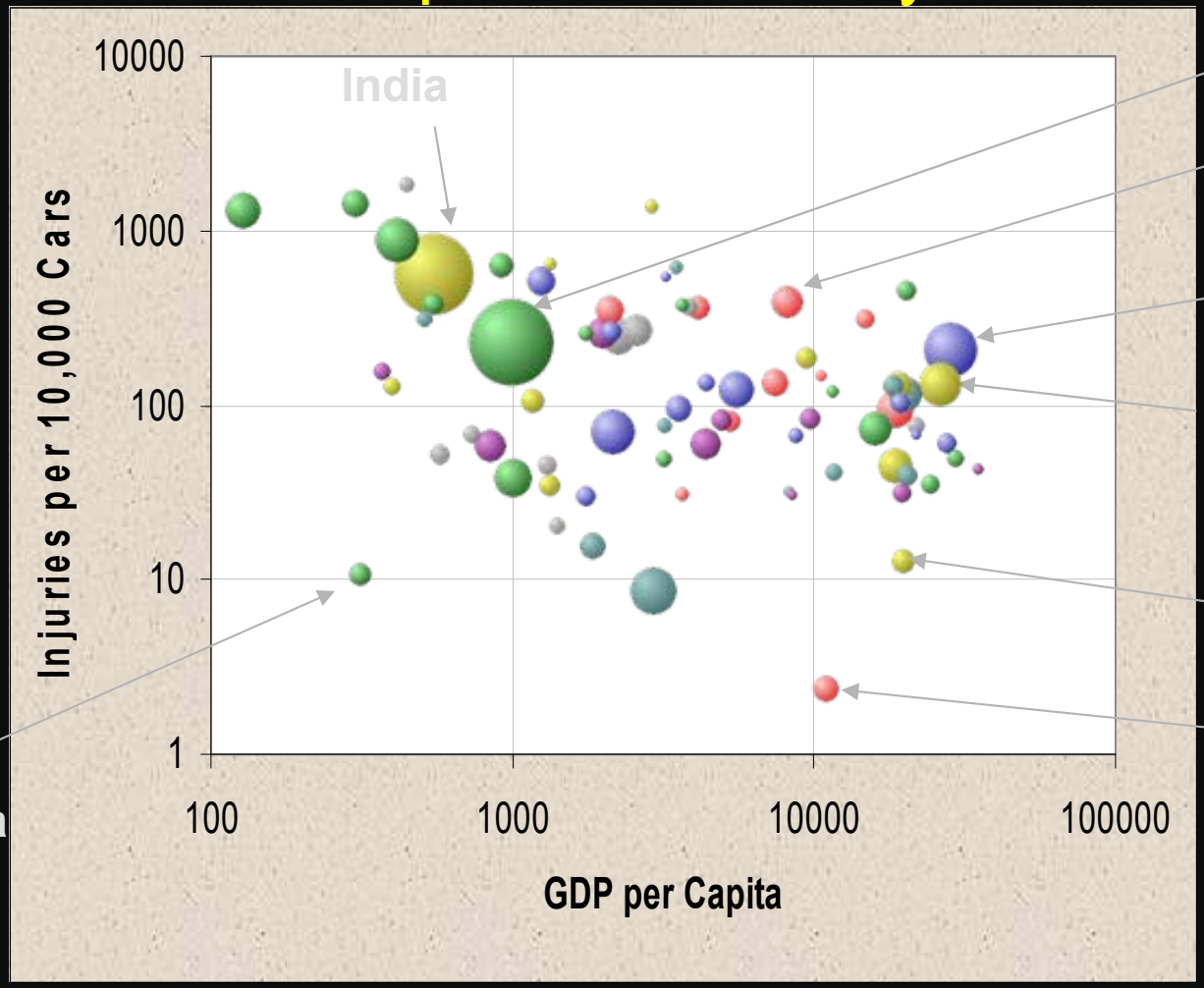
Outline of Talk

1. ITS Trends & Evolution
2. Standards & Architectures
3. ITS Research
4. ITS New Applications
5. Conclusion

This keynote was also previously given at IFIP Networking Conference, 2008.

Accidents are still prevalent today,,,,,,,,

TREND #1



Drivers Are not Perfect Humans!

Annual Injuries per 10,000 Cars vs. GDP

TREND #2

Insurance Cost is not going down!

TOP TEN MOST EXPENSIVE AND LEAST EXPENSIVE STATES FOR AUTOMOBILE INSURANCE, 2007 (1)

Rank	Most expensive states	Average expenditure	Rank	Least expensive states	Average expenditure
1	D.C.	$1,140	1	North Dakota	$512
2	New Jersey	1,104	2	Iowa	518
3	Louisiana	1,096	3	South Dakota	534
4	New York	1,047	4	Nebraska	554
5	Florida	1,043	5	Idaho	564
6	Rhode Island	1,017	6	Kansas	568
7	Delaware	1,012	7	Wisconsin	582
8	Nevada	1,000	8	North Carolina	591
9	Massachusetts	981	9	Maine	611
10	Connecticut	964	10	Indiana	618

(1) Based on average automobile insurance expenditures.

Source: © 2009 National Association of Insurance Commissioners.

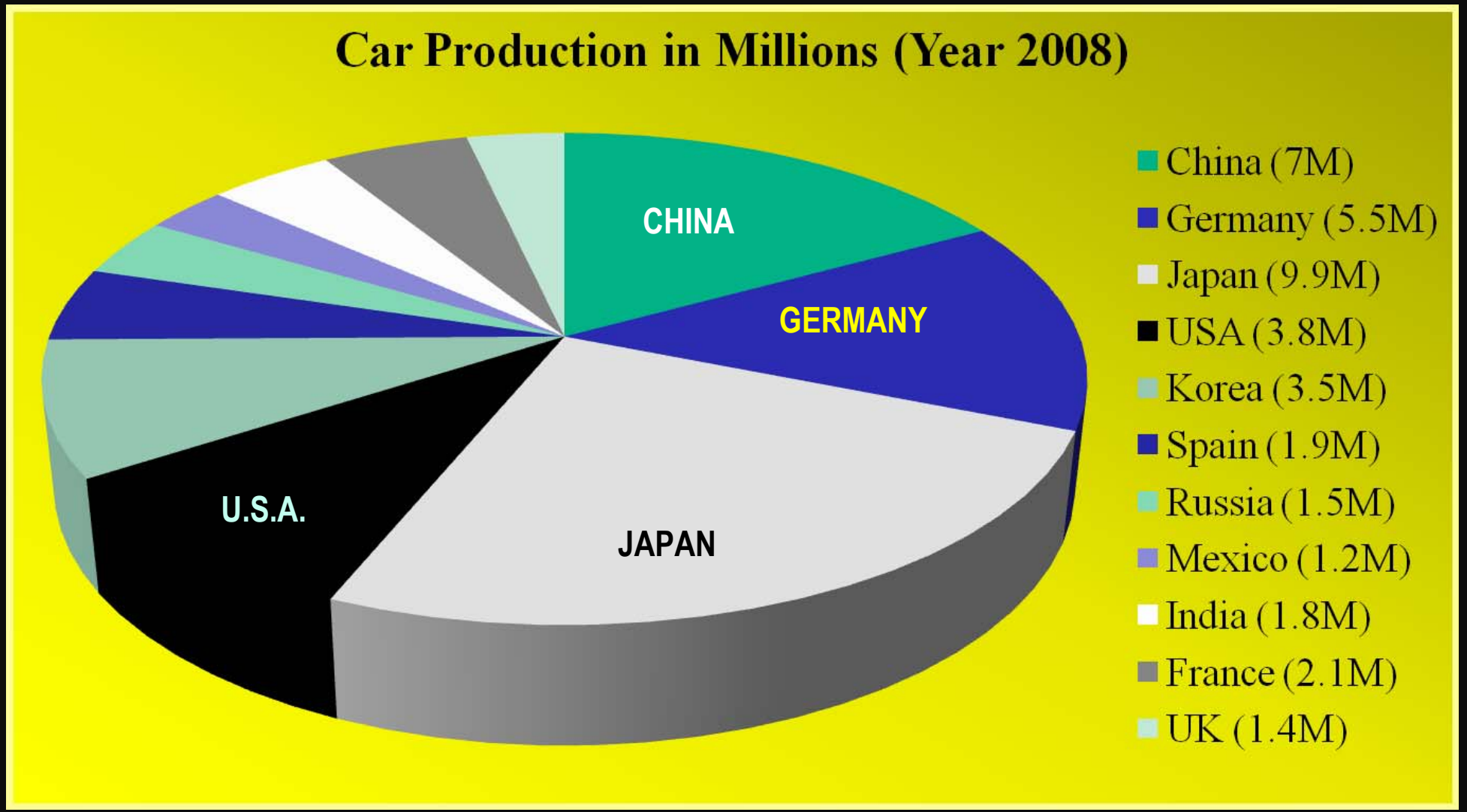
TREND #3

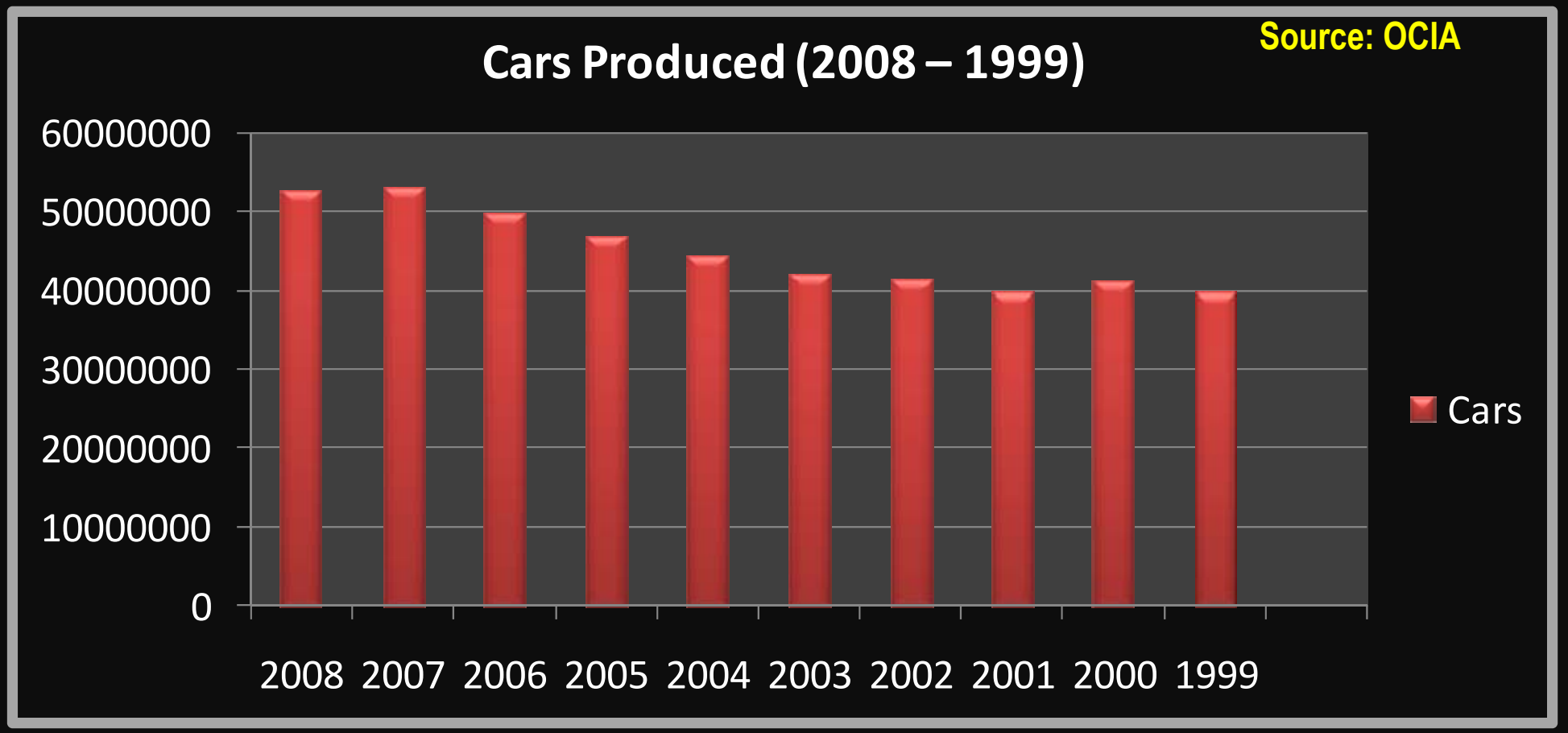
We love our cars!!

- Cars and roads fulfill our transportation needs
- Roads and highways are our transportation "superhighway"

Number of cars have been rising!

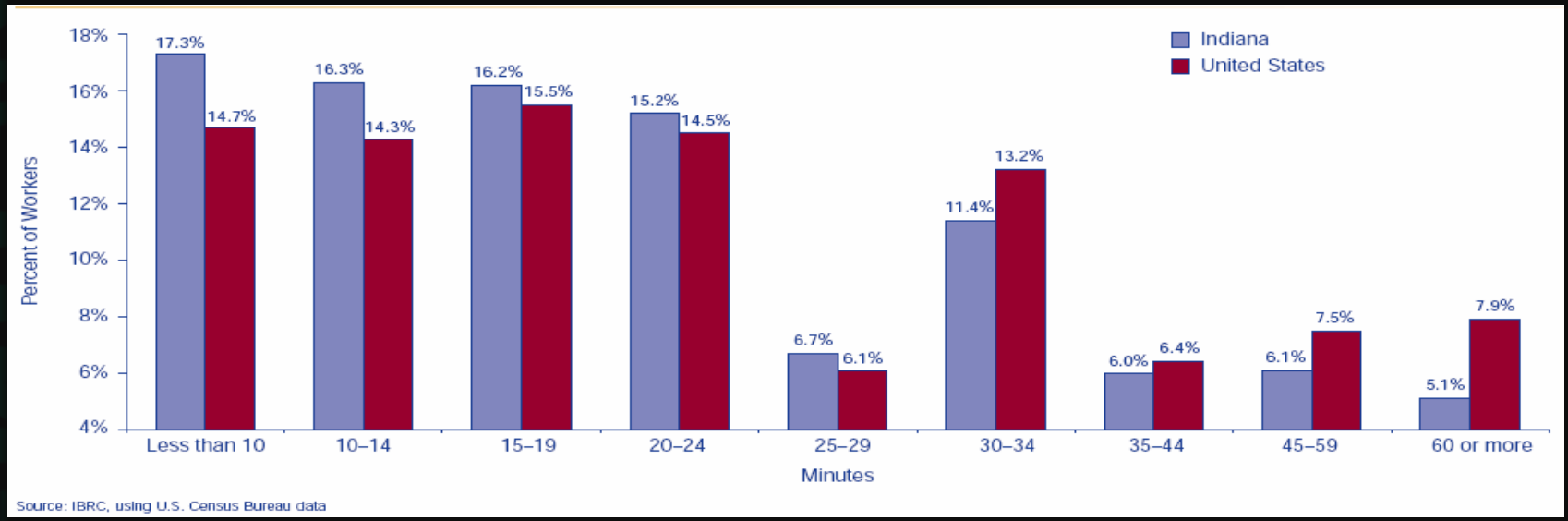
- How many cars in USA, China, India, Korea, Japan, etc? Do you know? (China = 27million) (India=4.8million) (USA=136million)
- 600 Million passenger cars in the world today!
- Huge business and it concerns our lives!


Car Production in Millions (Year 2008)
CHINA
GERMANY
JAPAN
U.S.A.
China (7M)
Germany (5.5M)
Japan (9.9M)
USA (3.8M)
Korea (3.5M)
Spain (1.9M)
Russia (1.5M)
Mexico (1.2M)
India (1.8M)
France (2.1M)
UK (1.4M)


Cars Produced (2008 – 1999)
Source: OCIA
60000000
50000000
40000000
30000000
20000000
10000000
0
2008 2007 2006 2005 2004 2003 2002 2001 2000 1999
Cars

TREND #4

Increasing Time spent on the Road – Time is $



Time = Destination + Your Speed + Congestion State + Other Factors

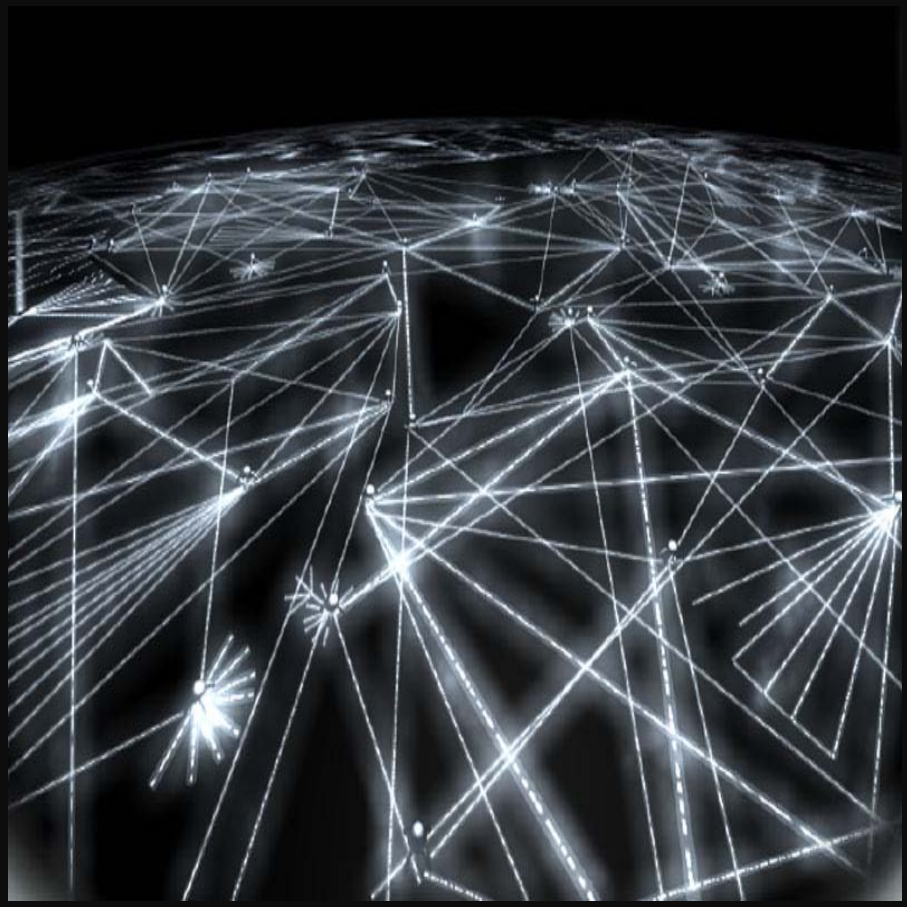
Interstate traveling time is much higher!!!

8 hours drive from Los Angeles to San Francisco on 405/101 Highway

TREND #5

The Time has come:

+



Transportation Highway meets the Information Superhighway!!!

ITS Evolution

Past ITS – Part 1

1. Focus was on civil engineering!
2. Focus on building efficient roads, highways, freeways, signs,,,.

Past ITS – Part 2

1. Focus was on mechanical/automotive engineering
2. Focus on building faster and powerful cars
3. For driving at high speed and long distances (as in USA)

ITS Evolution

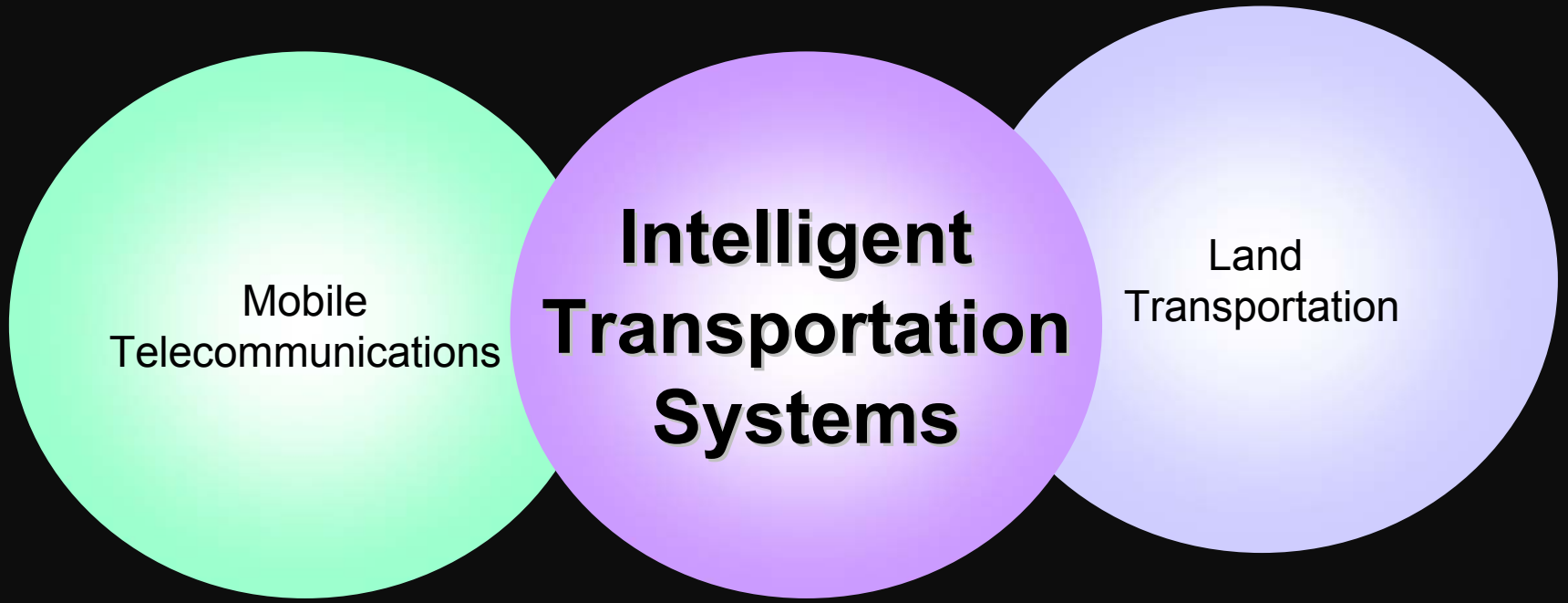
Past ITS – Part 3

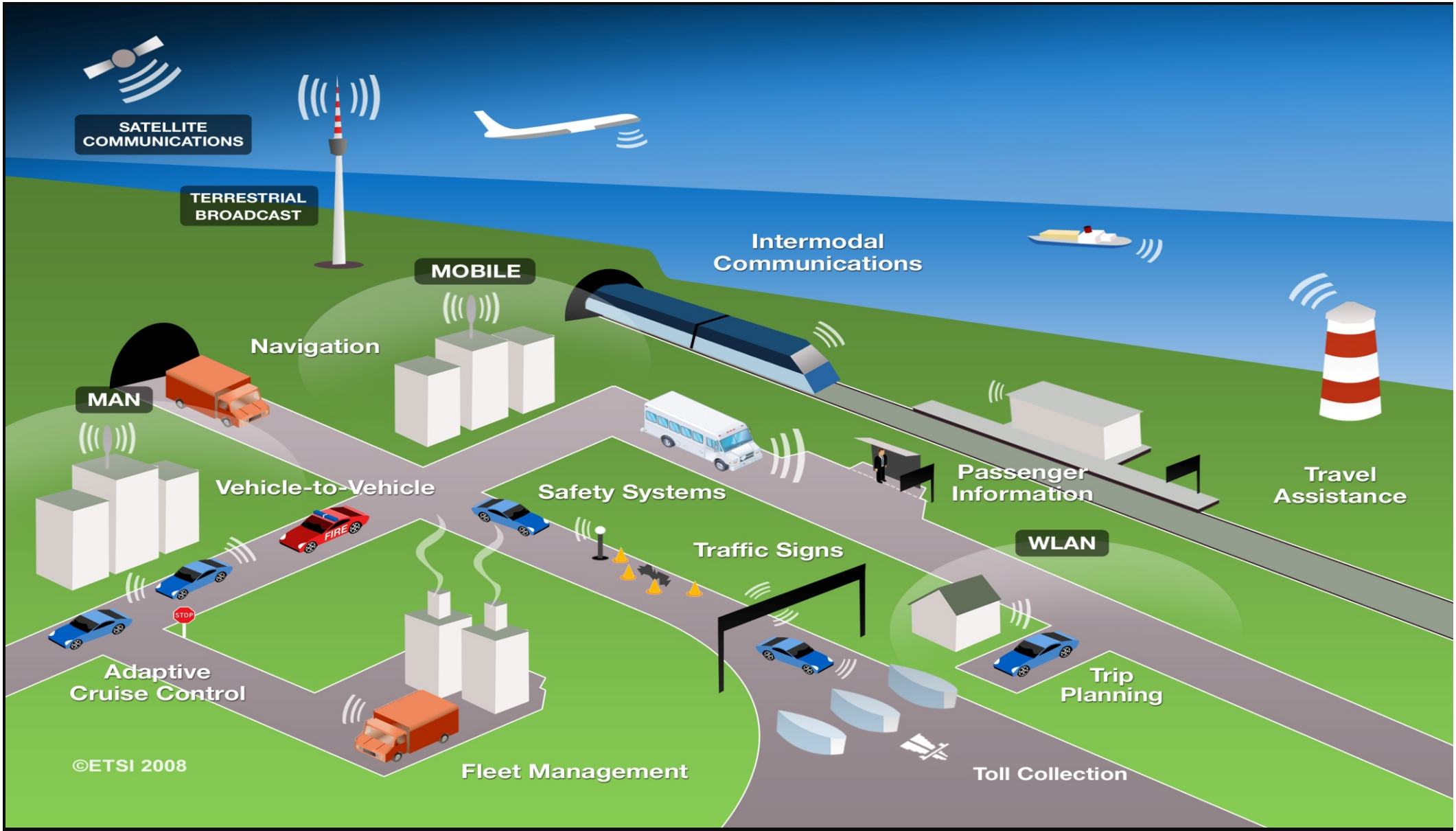
1. Focus on electronics engineering
2. Build safer cars, with more electronic sensors
3. Electronic control for seats, audio, meters, etc.

Now ITS – Part 4

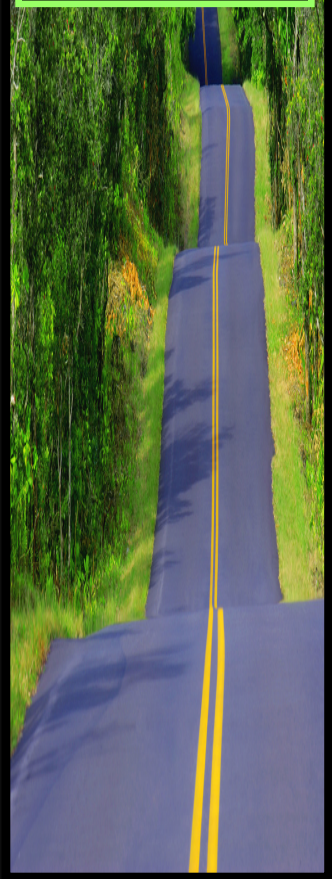
1. Focus is on embedding mobile telecoms/networks
2. Car-to-car ad hoc wireless networks (Vehicular Networks)
3. Mobile-comms-enabled IT highways

What is ITS? ITS is a Fusion Topic !




SATELLITE COMMUNICATIONS
TERRESTRIAL BROADCAST
MOBILE
Intermodal Communications
Navigation
MAN
Vehicle-to-Vehicle
Safety Systems
Passenger Information
Travel Assistance
WLAN
Traffic Signs
Adaptive Cruise Control
Trip Planning
©ETSI 2008
Fleet Management
Toll Collection

What is ITS?



Intelligent Infrastructure

- Arterial Management
- Freeway Management
- Transit Management
- Incident Management
- Emergency Management
- Electronic Payment and Pricing
- Traveler Information
- Information Management
- Crash Prevention and Safety
- Roadway Operations and Maintenance
- Road Weather Management
- Commercial Vehicle Operations
- Intermodal Freight

Intelligent Vehicles

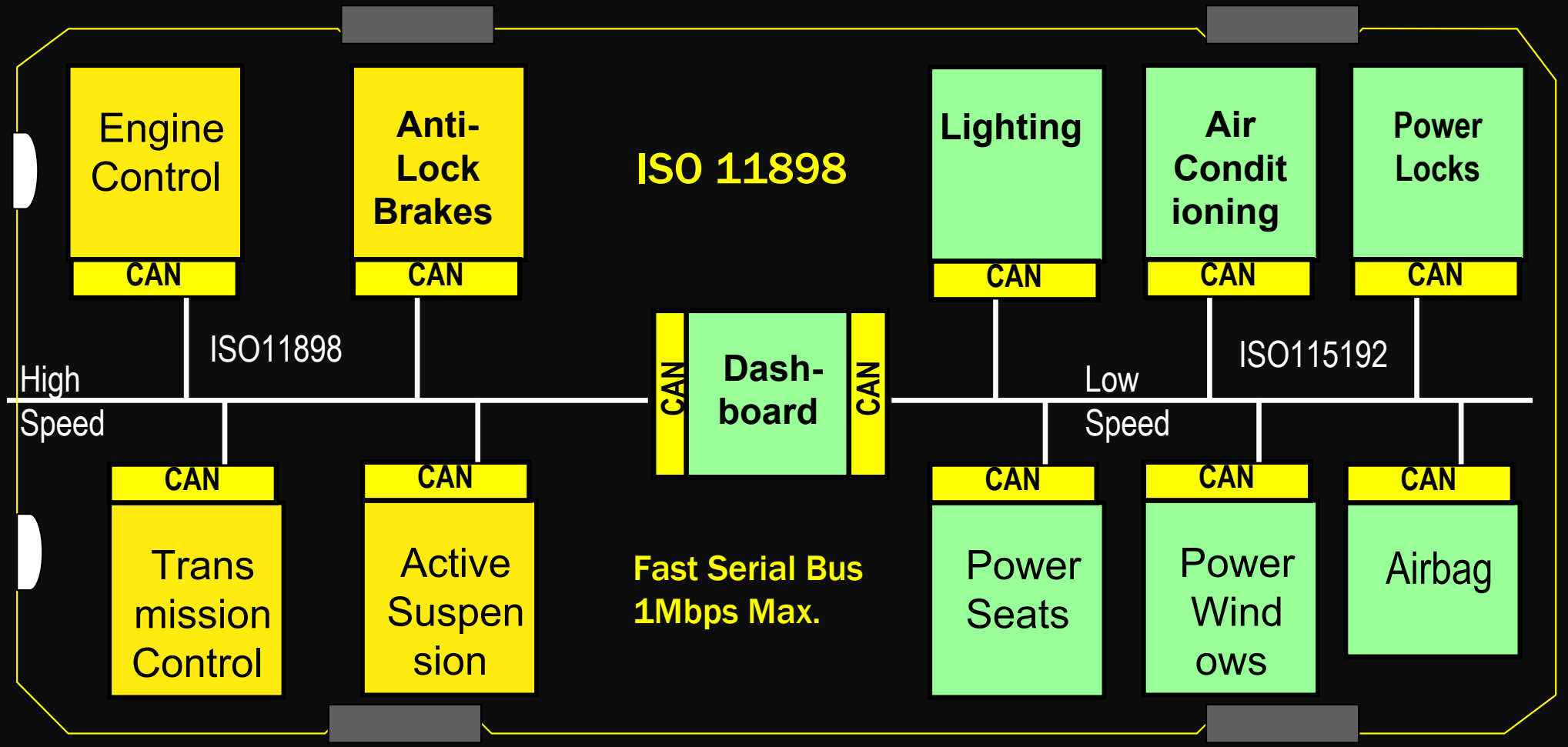
- Collision Avoidance Systems
- Driver Assistance Systems
- Collision Notification Systems

ITS Standards & Programs

Intra-Car Standardization

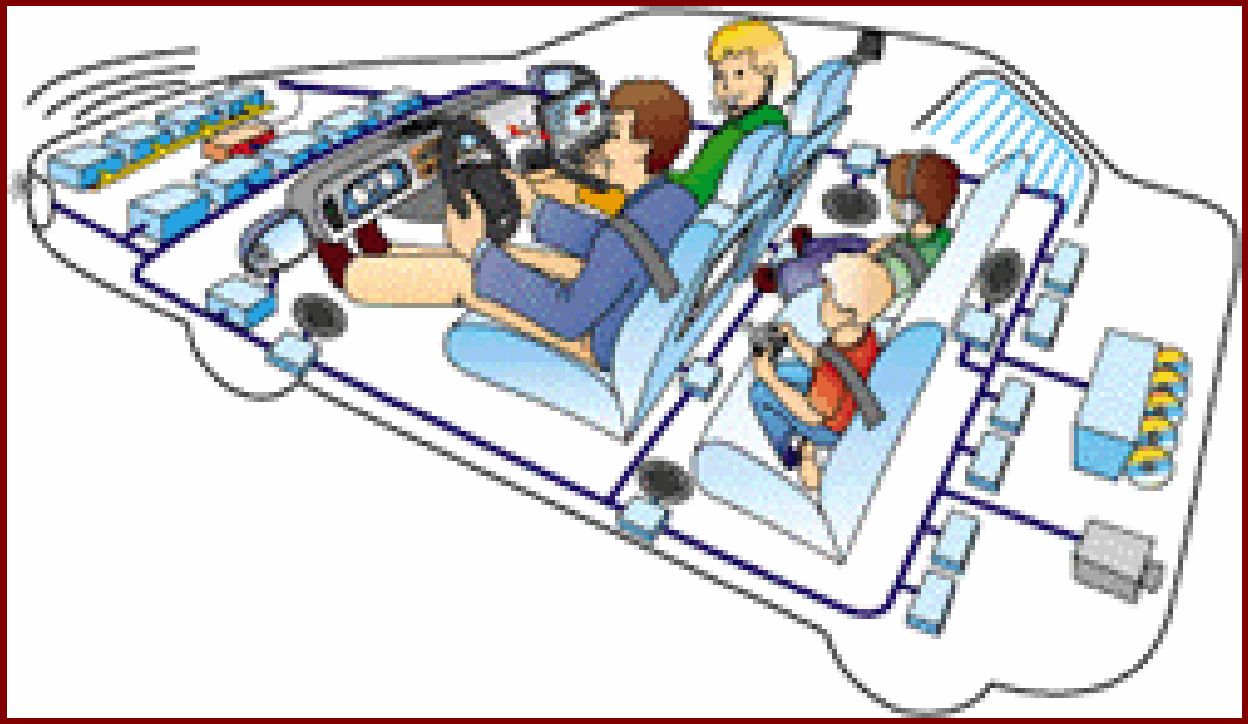
Inter-Car Standardization

Standards for Intra-Car Interconnection: CAN (Controller Area Network)



Originally developed by German Company Robert Bosch

Intra-Car Communications



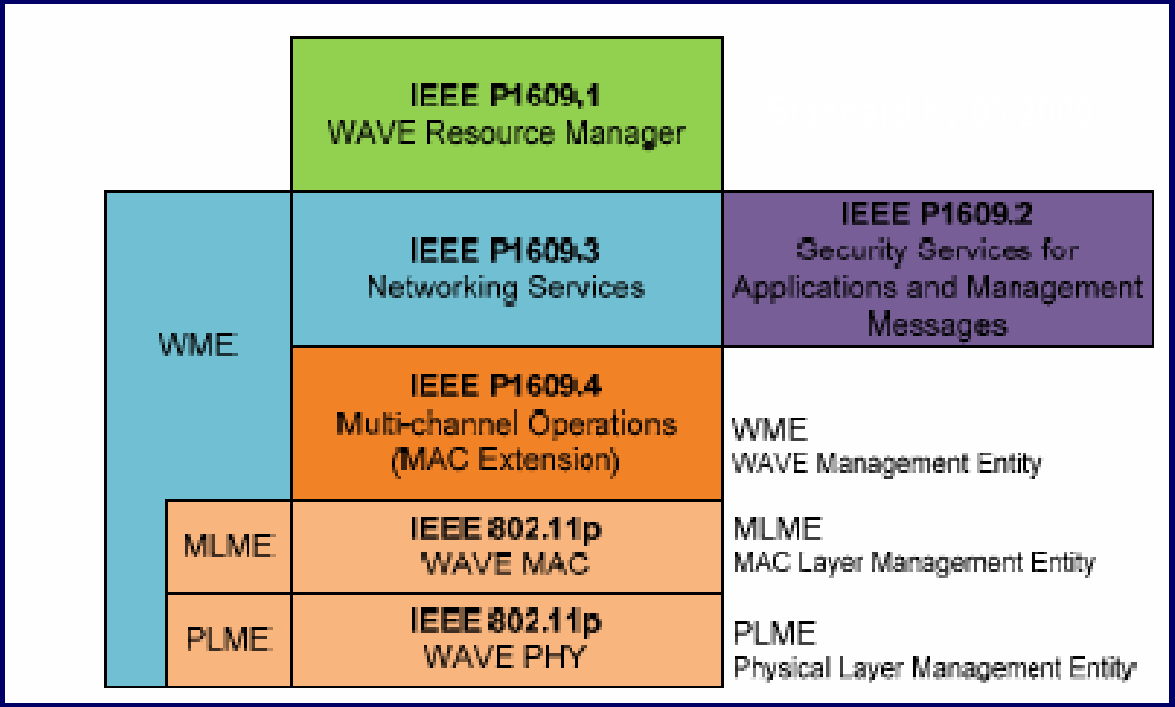
MANY OPTIONS

- **BLUETOOTH**
  [1m, 10m, 100m] 2.4GHz
- **CAN**
- **SERIAL**
- **INFRA-RED**
- **ETHERNET?**
- **UWB ?**
  802.15.4 PAN / up 10GHz

Controller Area Network – Fast Serial Bus 1Mbps max

Inter-Car Communications (802.11p WAVE?)

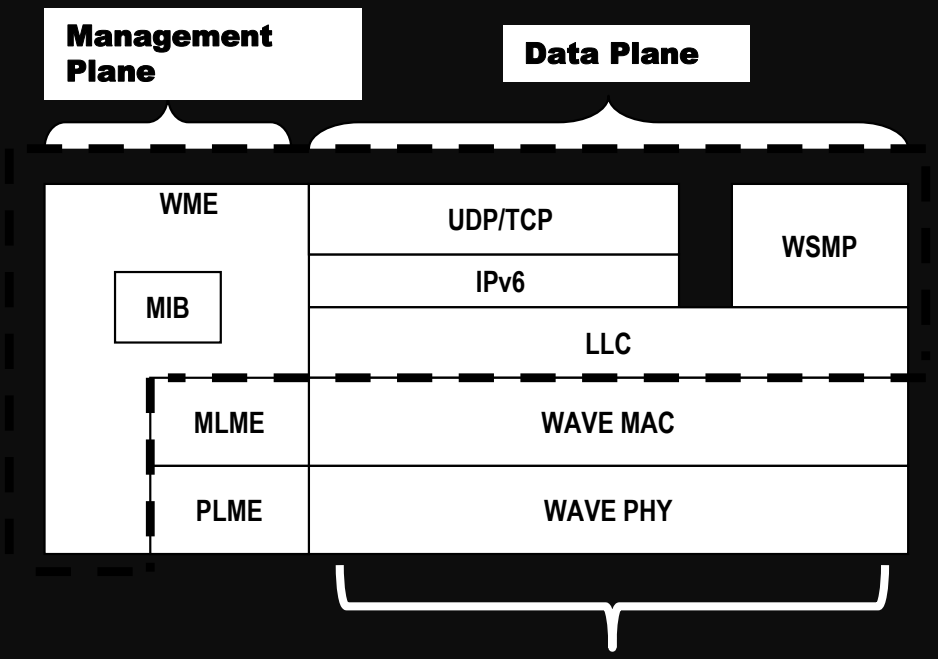
- CALM
- IEEE
- 802.11p
- 802.11s
- 802.11a



Status: http://grouper.ieee.org/groups/802/11/Reports/tgp_update.htm

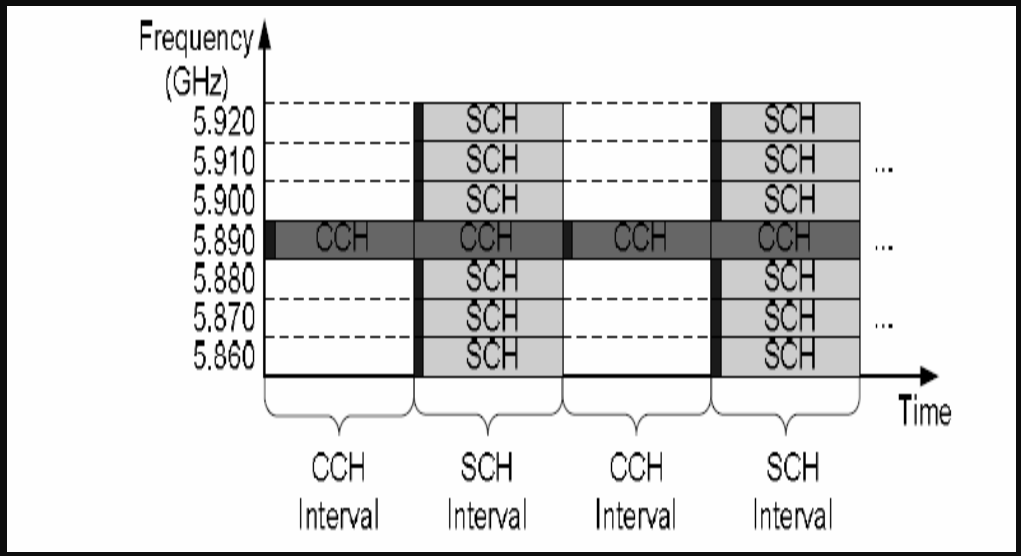
WAVE = Wireless Access in Vehicular Environments

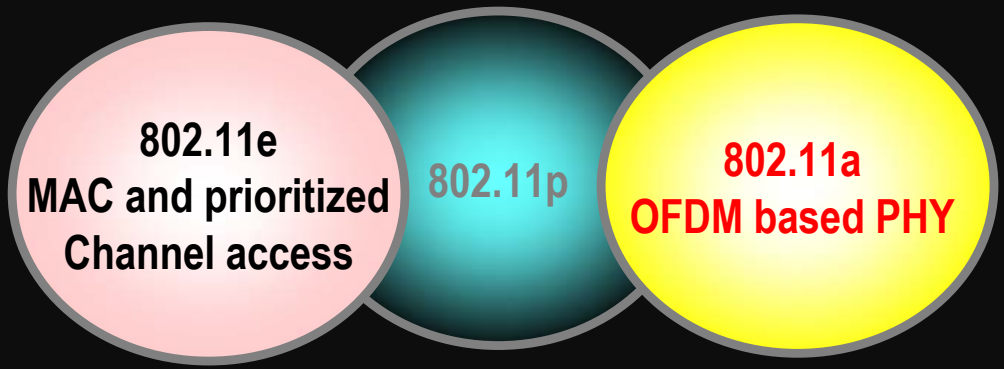
WAVE Protocol Stack



WAVE Short Message (1400bytes)
Control & Service Channels
Multichannel operations
PHY OFDM 5.9GHz

WAVE Multi-Channel Operations



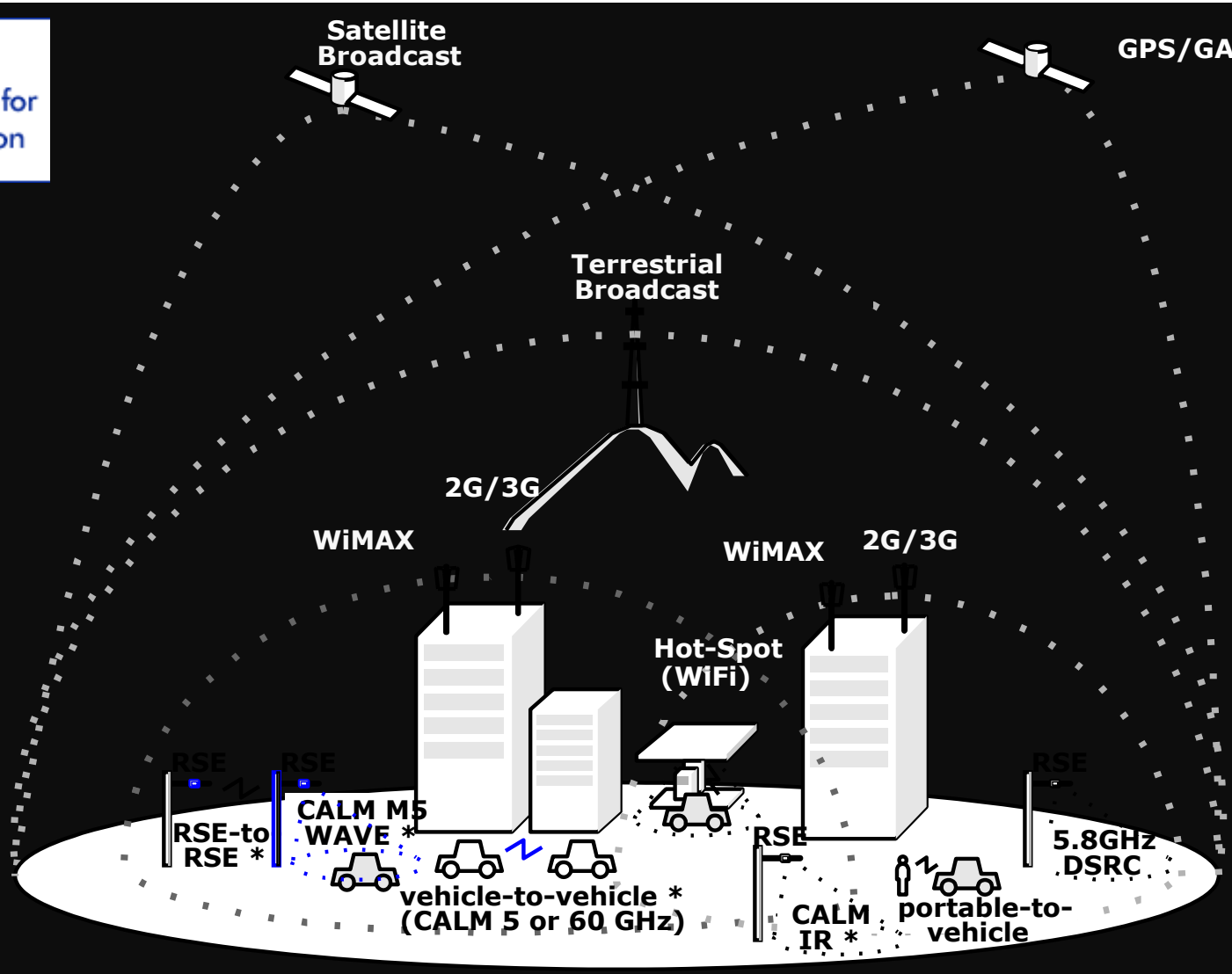


International Organization for Standardization

CALM – Continuous Air Interface for Long & Medium Distance

ISO TC 204 WG 16

GPRS+WLAN



CALM Protocol Stack

CME CALM Manager ISO 21210

CME Registration of Ingress/Egress Interfaces

Application Management ISO 24101

Non-CALM-aware ISO 15628-based APPLICATIONS

Non-CALM-aware IP (Internet) APPLICATIONS

CALM-Aware APPLICATIONS

Convergence Layer Part of ISO 15628 ISO 21210

Convergence Layer IP socket/ ISO 21210

TCP/UDP/ INTERNET STANDARDS

NME Network Manager ISO 21210

NETWORK INTERFACE
Routing and Media Switching based on IPv6
ISO 21210

IME Interface Manager ISO 24102

ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218	ISO 21218
ISO 21212 2G Cell Manager	ISO 21213 3G Cell Manager	ISO 21214 IR Manager	ISO 21215 W-LAN Manager	ISO 21216 Millimeter Manager	ISO 24103 DSRC ISO15628	ISO 24xxx W-MAN Manager	ISO 24xxx Broadcast Manager	ISO 24xxx PAN Manager	ISO 24xxx Wired Manager
… GPRS EDGE	… cdma2k UMTS	… IR-B IR-A	… WiFi M5	RADAR MM-J MM-E	K-DSRC J-DSRC C-DSRC	… HC-SDMA WiMAX	… DAB GPS	… W-USB BlueT	Ether AMIC CAN

CALM Media | External Media | CALM Network | 21218 = LSAP | Applications

SAP Data SAP SAP Management SAP

CAR 2 CAR COMMUNICATION CONSORTIUM

IN EUROPE

Audi OPEL

FIAT

RENAULT

BMW Group

DAIMLERCHRYSLER

Objectives:

1. Create open standard for C-2-C comms based on WLANs.
2. Development of safety applications
3. Strive for free European wide Frequency band for C-2-C comms
4. Develop business models for market penetration

ITS Internet Consortium In JAPAN

Objectives:

1. Create development scenarios for ITSI
2. Promote and standardize ITSI technologies
3. Incubate new business

SOURCE :
http://www.internetits.org

Internet ITS

TC 204 – Intelligent Transport Systems

Scope: Standardization of information, communication, and control systems In the field of urban and rural surface transportation, including traffic Management, traveller information, emergency services, etc.

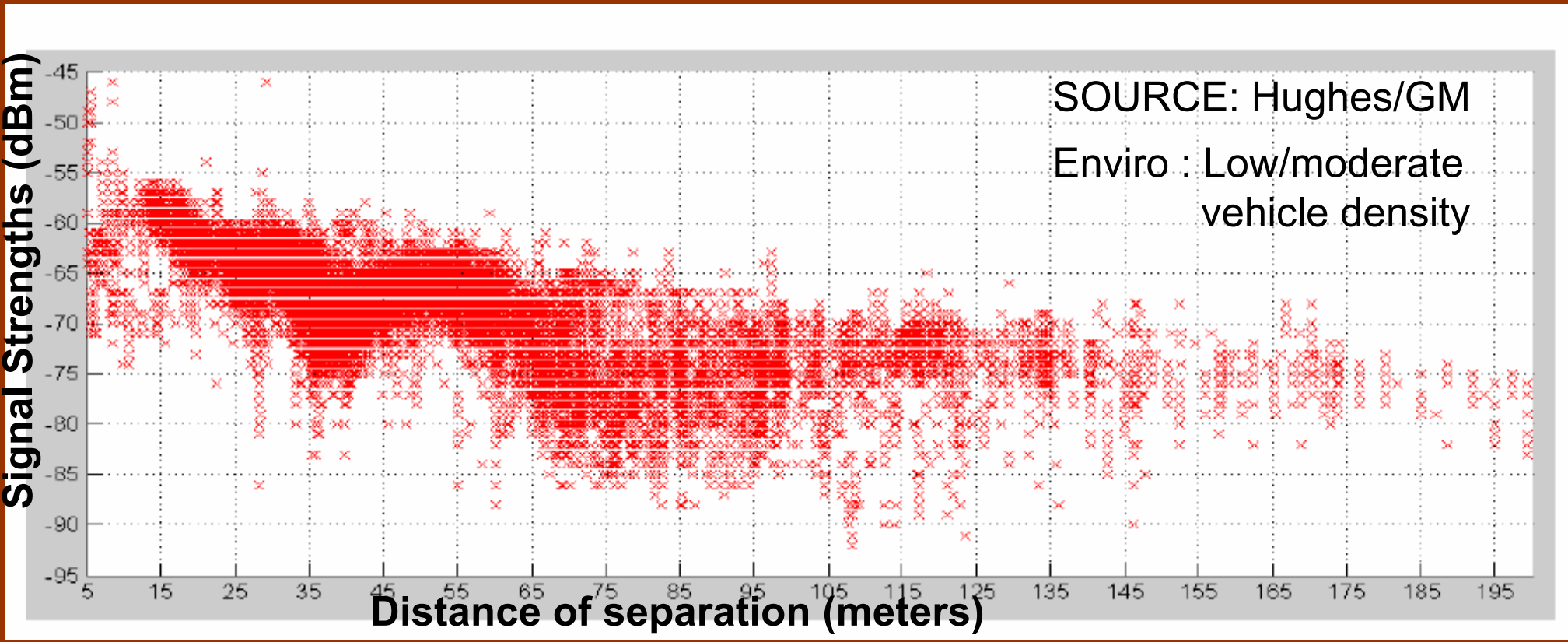
Working Groups (WG)	Technical Coverage
TC204 / WG 1	Architecture
TC204 / WG 3	Database Technology
TC204 / WG 4	Automatic Vehicle & Equipment Identification
TC204 / WG 5	Fee and Toll Collection
TC204 / WG 7	General Fleet Management & Commercial Freight
TC204 / WG 8	Public Transport / Emergency
TC204 / WG 9	Integrated Transport Information, Management & Control
TC204 / WG 10	Traveller Information Systems
TC204 / WG 11	Route Guidance & Navigation Systems
TC204 / WG 14	Vehicule / Roadway Warning & Control Systems
→ TC204 / WG 15	Dedicated Short Range Communications (DSRC) for Applications
→ TC204 / WG 16	Wide Area Communications / Protocols and Interfaces

Many EU Sponsored Programs

AIDE – Adaptive Integrated Driver-Vehicle Interface
AIDER – Accident Information & Driver Emergency Rescue
ATLANTIC – A Thematic Long-term Approach to Networking for Telematics & ITS Community
PREVENT – Preventive & Active Safety Applications for Road Safety on European Roads
ADOSE – Reliable Application Specific Detection of Road Users with Vehicle On-Board Sensors
INTERSAFE – Cooperative Intersection Safety
SAFERIDER – Advanced Telematics for Enhancing Safety & Comfort of Motorcycle Riders
COOPERS – Cooperative Networks for Intelligent Road Safety
HIGHWAY – Intelligent Maps & Geographic Tools for Context-aware Delivery of E-Safety
I-WAY – Intelligent Cooperative Systems in Car for Road Safety
COMeSAFETY – Communications for E-Safety
CarTALK2000 – Advanced Driver Support System based on V2V Comms Technologies
SAFESPOT- Cooperative Vehicles & Road Infrastructure for Road Safety
CVIS – Cooperative Vehicle-Infrastructure Systems


ITS
Architectures

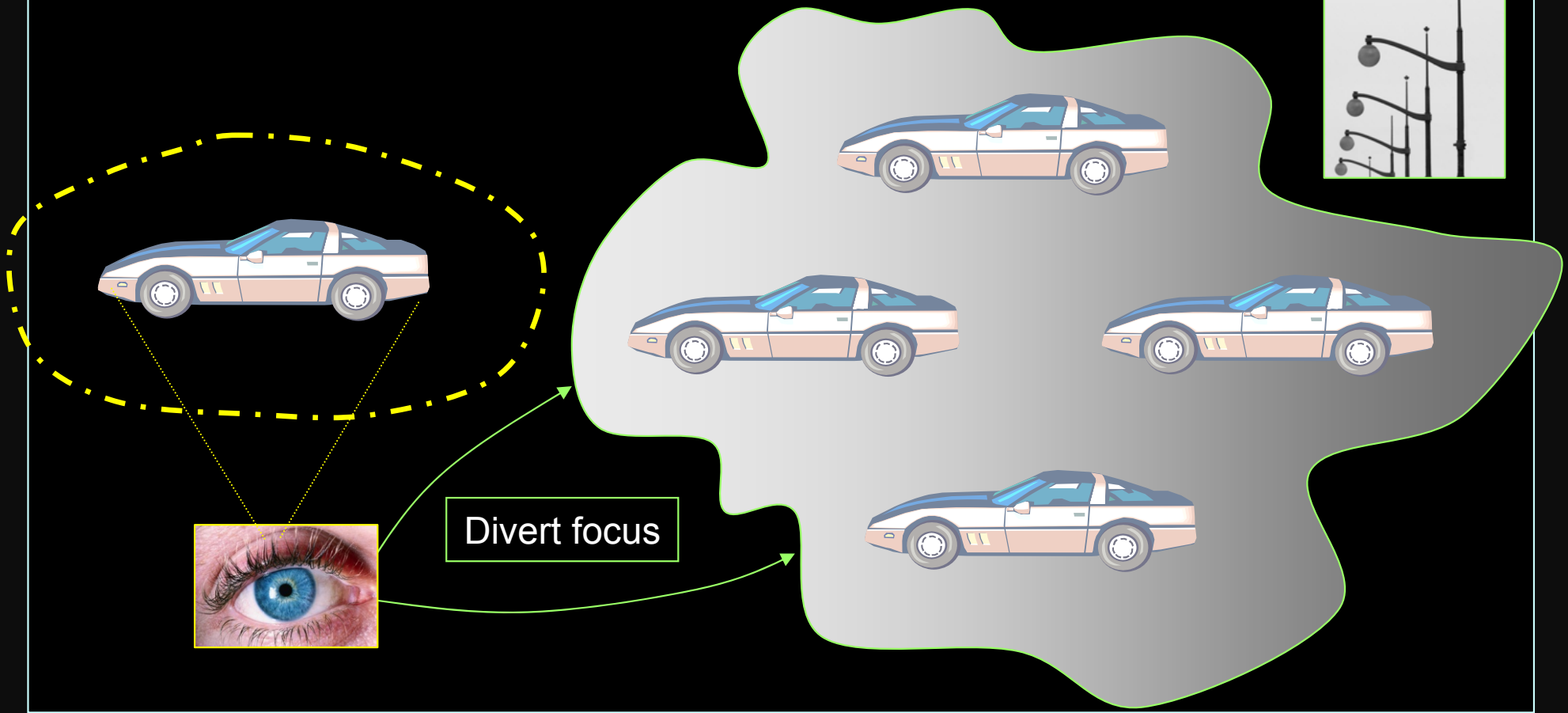
- Why Multi-hop for C2C comms?



- Communications between 2 cars getting weaker over distance with mobility
- Ad hoc; rapidly deployable; smart localized communications; Can reach other/further cars

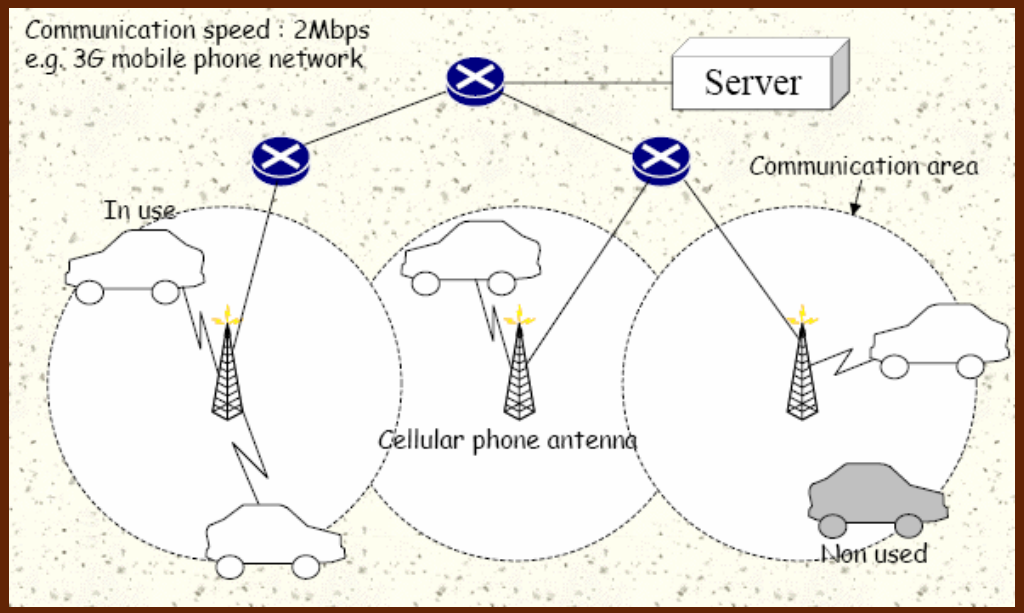
Architecures of Car-to-Car Networks

- Cars are not considered "ALONE"



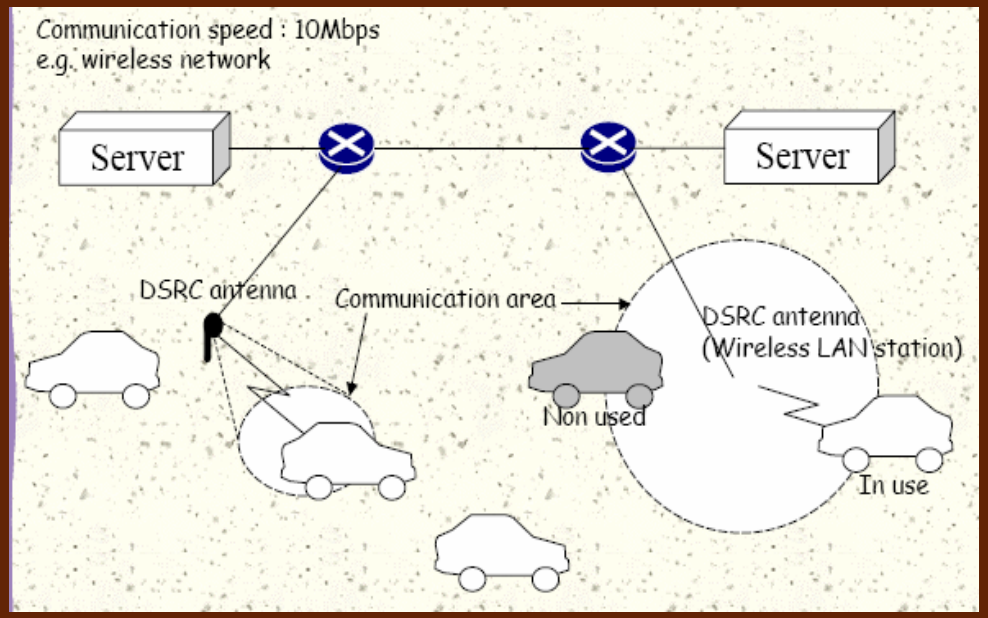
Architecures of Car-to-Car Networks

- Car2Cellular



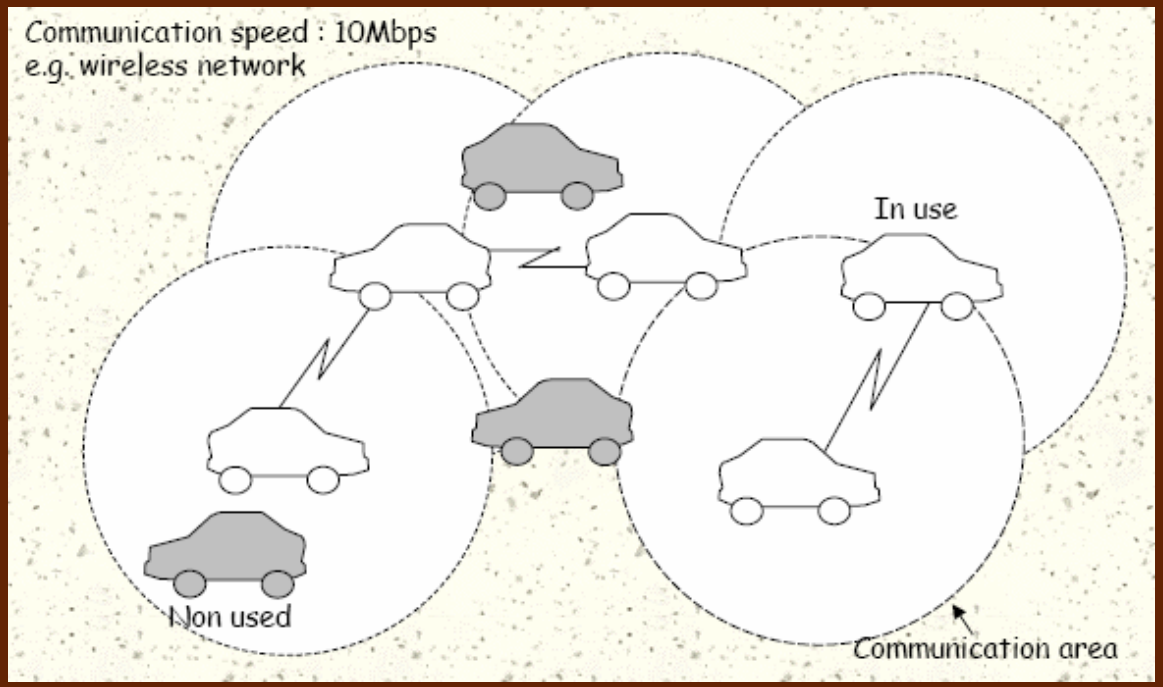
- Car to car comms via cellular
- Not quite 3G plan
- Costly way
- 3G core network needs ITS DB

- Car2RS



- Short range communications
- 5.8GHz DSRC
- Well understood technology
- But mostly 1-hop scenarios

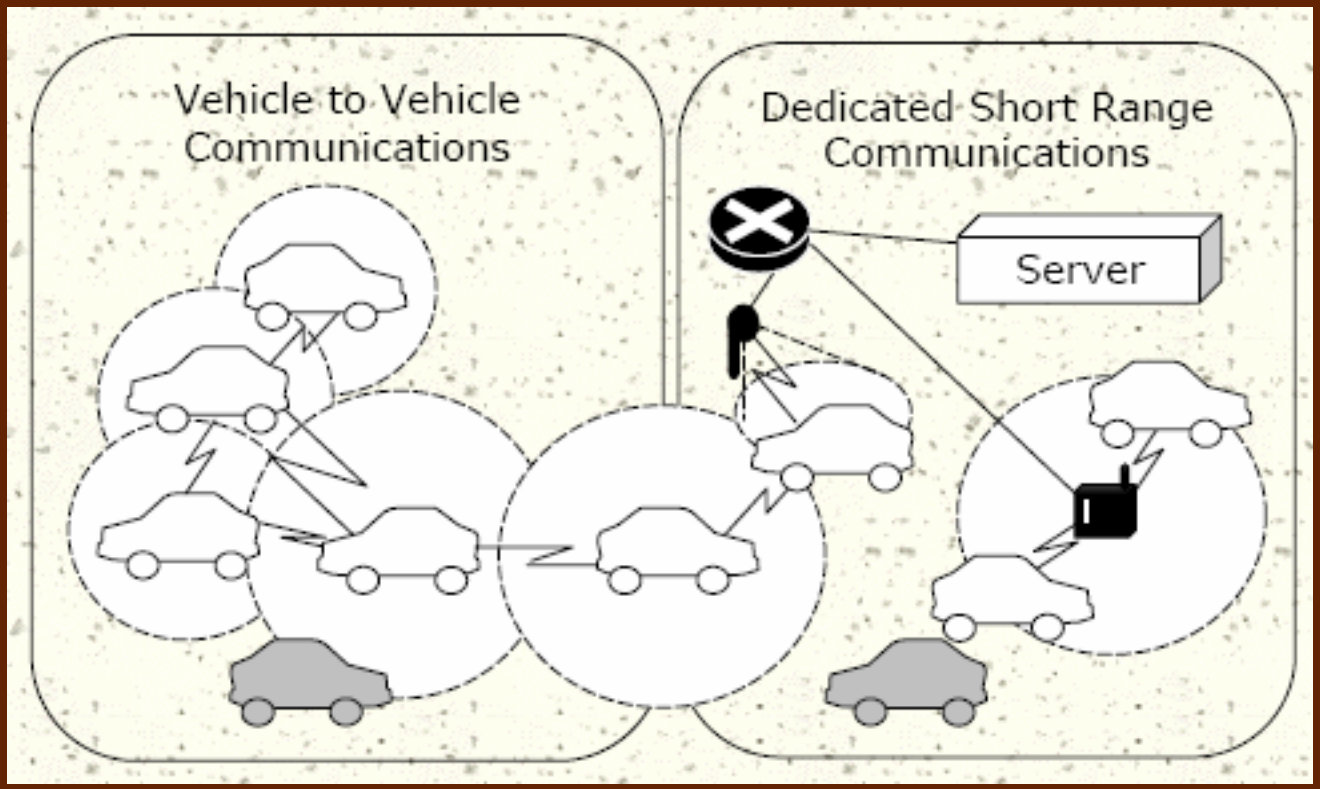
- Car2Car (new comms, new protocols,..)

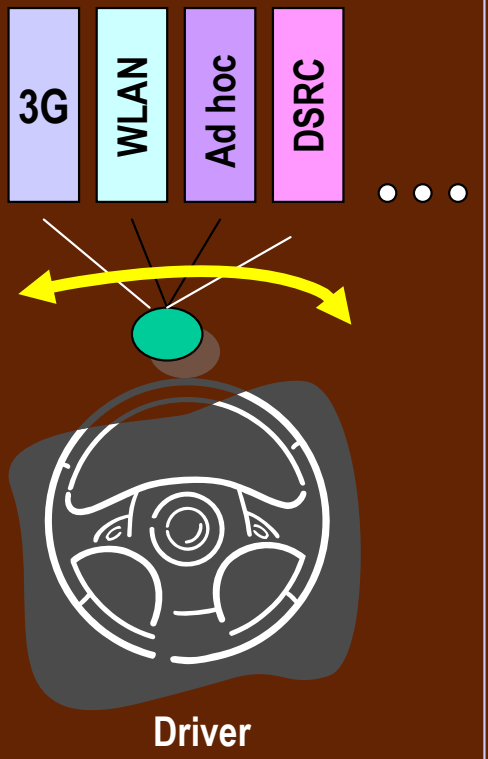


- New scenario
- Backed by ad hoc technology
- Great potential
- Great innovations
- In development
- Many guesses on wireless technologies:
  - 802.11b/a/n/g
  - 802.11p wave
  - 802.11s mesh
  - WiBro ? 802.16e
  - Infrared ?
  - Satellite ?
  - ? ? ?

- Vehicle = motorbikes, cars, trucks, vans, taxis,
- Mobility = Group and movement constrained by road and highway
- Speed = from 0 – 90 miles/hour (USA)

- Hybrid Scenarios – Why not?



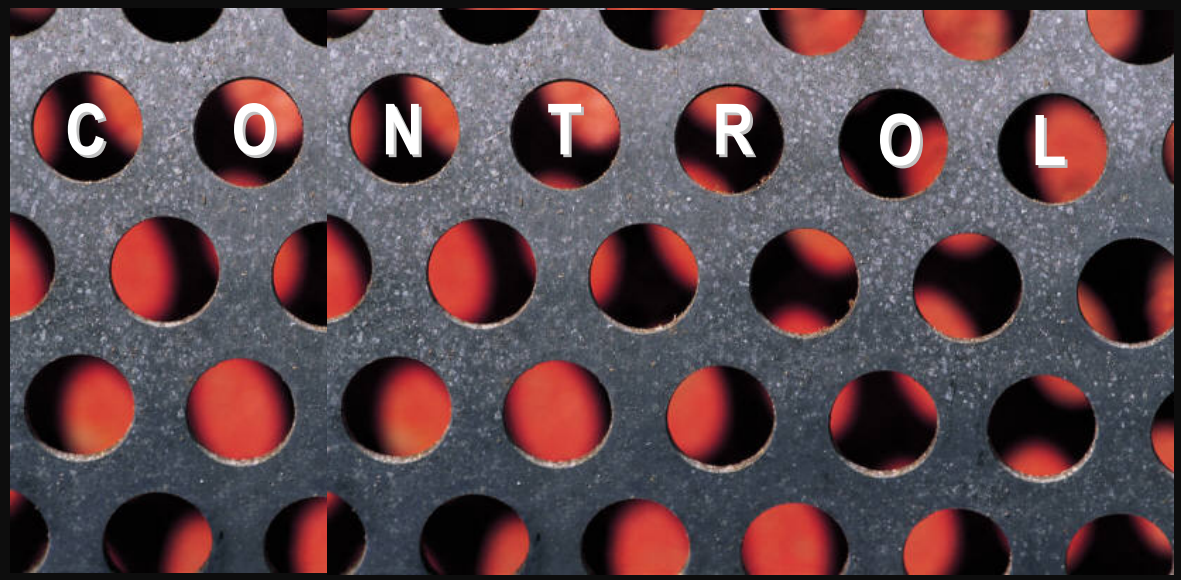



Research

Compelling Questions for Researchers

1. What "types of data" traffic exist in ITS?
2. What impact of car mobility on "data traffic flow"?
3. How is vehicular "mobility" handled?
4. How we do "channel access" for moving vehicles?
5. How we do "routing/rebroadcasting" for moving vehicles?
6. Can we support "multicast"?

2 "Planes" of ITS Networking Research



CK's View of "CONTROL" plane of ITS Networking

Research

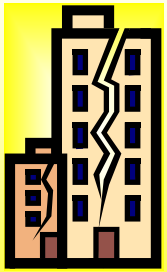
1. Propagation of "**vehicular traffic condition**" is important

   Vehicular traffic conditions include:

   - Car accidents
   - Car stalled (out of gas, engine failure, etc)
   - Jam
   - Natural disasters
     - **Cracks on road (earthquake)**
     - **Ice on road (winter time)**
     - **Poor visibility (fog & heavy rain)**
     - **Slippery (heavy rain & floods)**

2. **Dangerous Drivers**

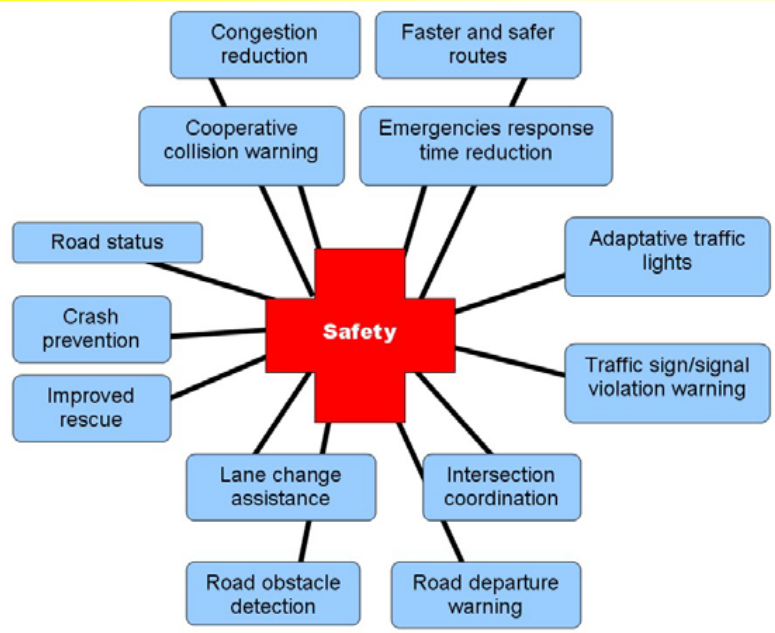
   - **Drunk Drivers**
   - **Reckless Drivers**
   - **Criminals On-the-run**
   - **Fatigue Drivers**

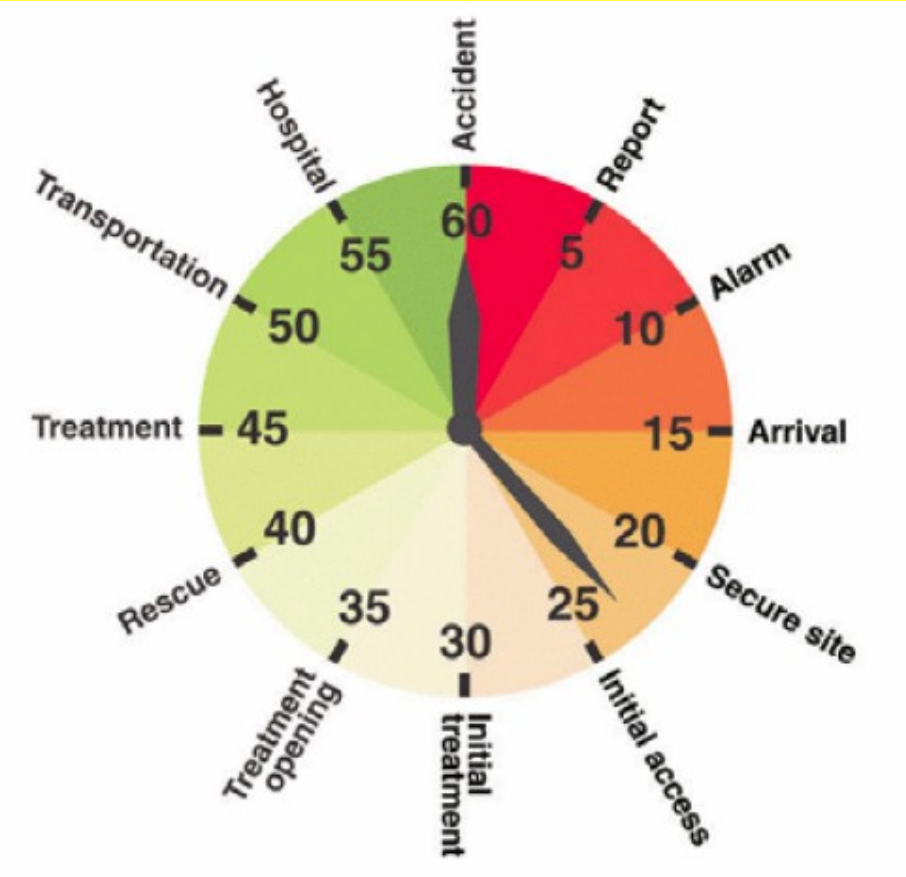


CK's View of "CONTROL" plane of ITS Networking

3. Rescue Operation

- Localized rescue possible
- Reduce Rescue Delay
- Safe lives readily





CK's view of "DATA" plane of ITS

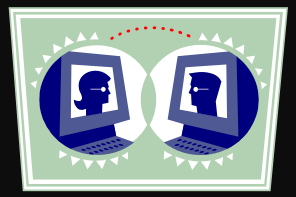
Research

1. Email data?
2. Information access (Server download)?
3. Multimedia News?
4. Remote work & Login (telnet, etc)
5. Video conferencing?
6. Multimedia computing?

KEY

It is hard to do computing while driving at the same time, unless we are talking about passengers who are not drivers.

Most data access can be done via cellular


"DATA" plane of ITS

research

- Wireless Comms
- Radio Propagation Models
- Media Access
- AD HOC Routing
- Multicasting
- Addressing
- TCP
- Gateway
- Mobility support
- Protocol stack
- INTEROPERABILITY
- QoS
- Cooperative Behavior
- Security

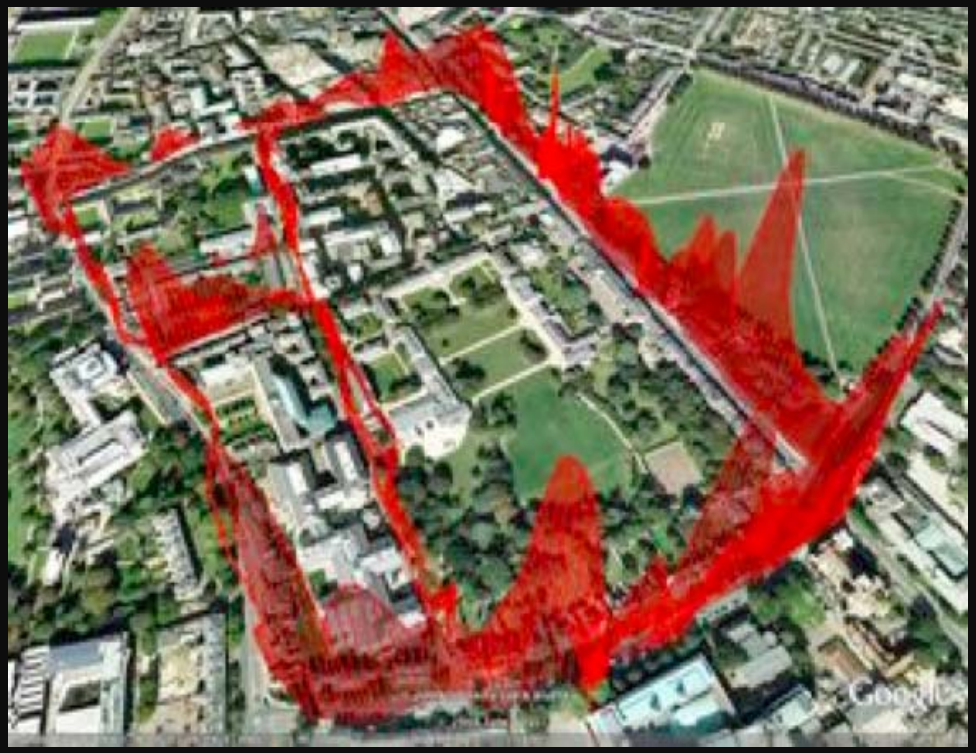
"CONTROL" plane of

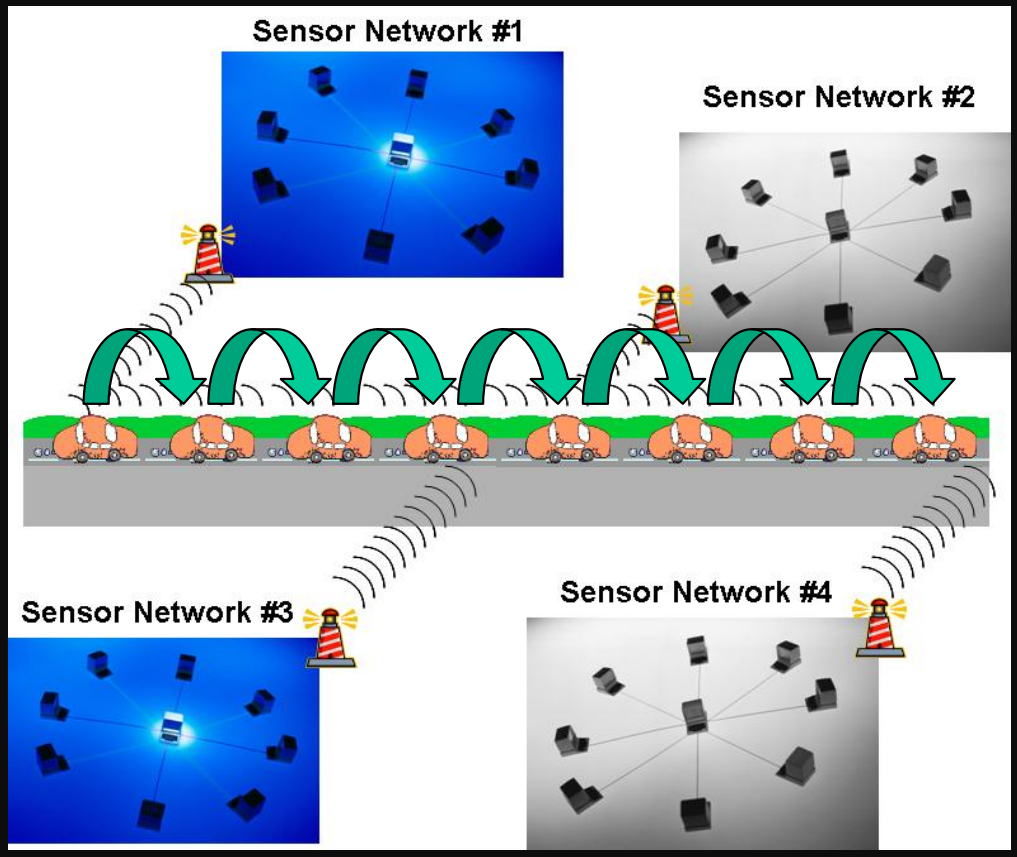
RESEARCH

- Control info dissemination
- Media access Control for emergency messages
- Routing / Broadcasting
- Beacons
- Traffic/road info gathering & fusion
- Control-based applications
- Pre/Post Crash Safety Mgmt
- Sensor data gathering
- Distributed detection of Dangerous vehicles
- CHARGING
- SECURITY

I. Cars to collect Sensors' Data.

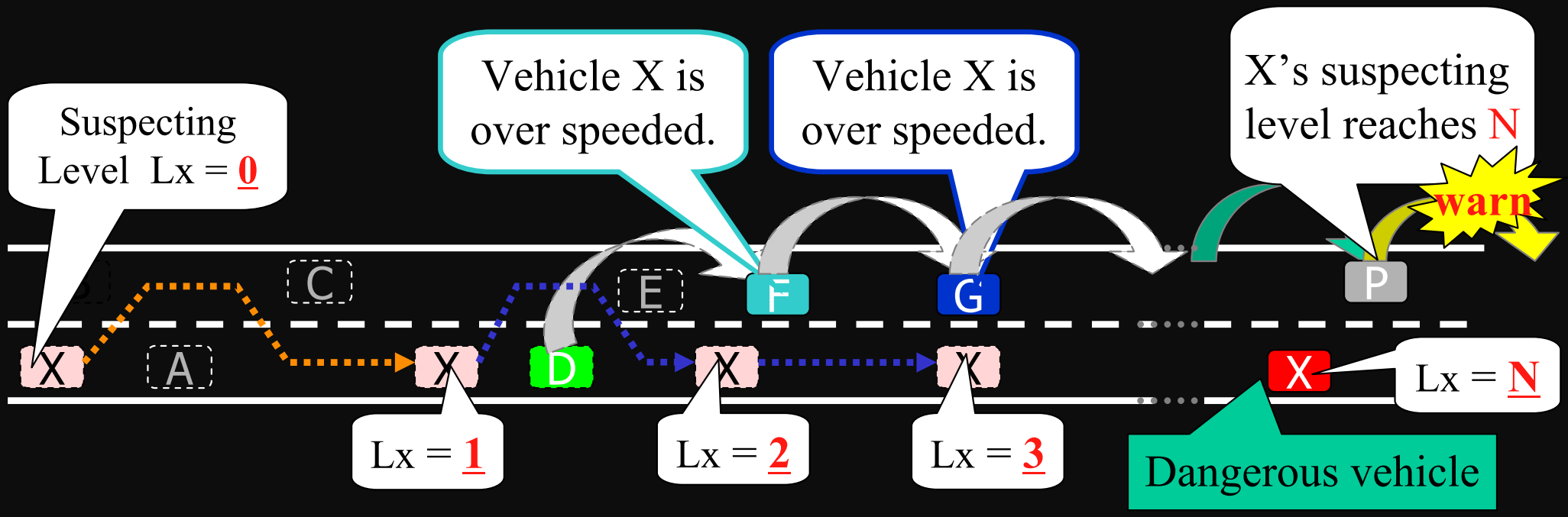
II. Cars as mobile sensors for environmental pollution sensing.





Dangerous Cars

Distributed Detection of Dangerous Vehicles on Roads & Highways using Inter-Vehicular Ad Hoc Communications



References:
- K. Isu, T. Umedu, C K Toh, et. al. "Detecting Dangerous Vehicles for Intelligent Transportation Systems" Proc. IEEE GLOBECOM 2006
- T. Umedu, K. Isu, T. Higashino, and C K Toh, "An Inter-Vehicular Communication Protocol for Distributed Detection of Dangerous Vehicles", IEEE Transactions on Vehicular Technology, 2010

New Protocols for ITS

Distributed MAC Challenges
- Centralized slot allocation bad
- QoS is a serious challenge
- WAVE MAC is a good start

Distributed Routing Challenges
- Pure Broadcast routing inefficient
- Broadcast what? Data or Alert?
- Handoff what?

Distributed V2V Protocols for:
- Accident/ Harzard Warning
- Congestion Control
- Detection of Dangerous Drivers
- Pre/Post Crash Safety Mgmt

Distributed V2I Challenges
- Upload and reporting
- Vehicle Tracking
- Download needed software
- Environmental monitoring

Topics of Possible Research - in ITS Networking

1. Vehicular Sensing
2. Road Condition Sensing
3. Information Hovering
4. Traffic Data Aggregation
5. Car-2-X SDK
6. MAC Protocol Car-2-RSU
7. Automated Share Ride
8. Warning Message Dissemination Techniques
9. V2V Protocol for Collision Avoidance
10. V2V Protocol for Collision Notification
10. V2V Protocol for Congestion Notification & Avoidance
11. Position-based Rebroadcast
12. Software updates VANETs
13. Traffic Navigation using VANETs
14. Beaconing in VANETs
15. Special Routing
16. VANET Security
17. VANET Simulators
18. VANET Applications
19. Vehicular Gateways
20. Pre/Present/Post Crash Safety Mgmt
21. Vehicular "Black-box"

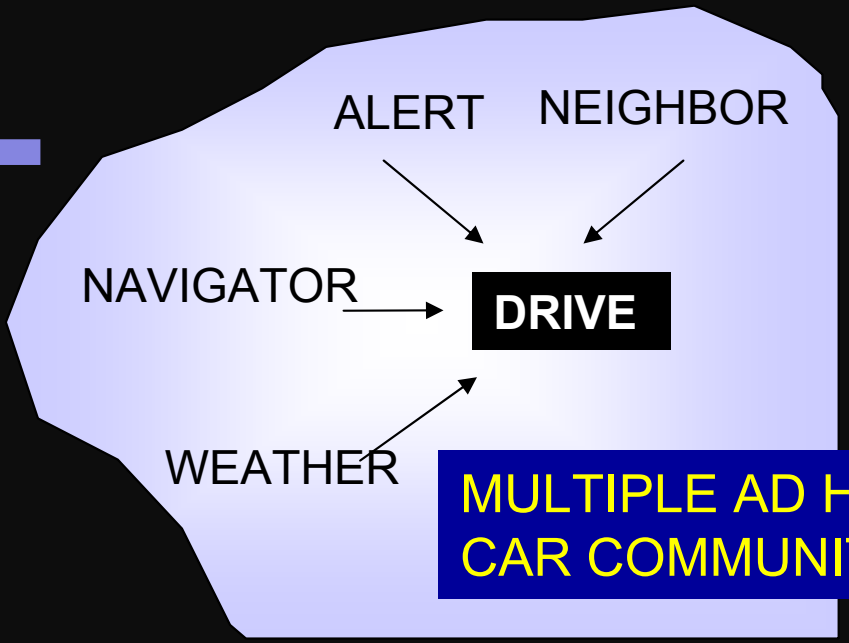
Ref: "Future Application Scenario of MANET-based Intelligent Transportation Systems" – Proc. Of IEEE FCGN Conference, 2007.

"4" ITS Applications

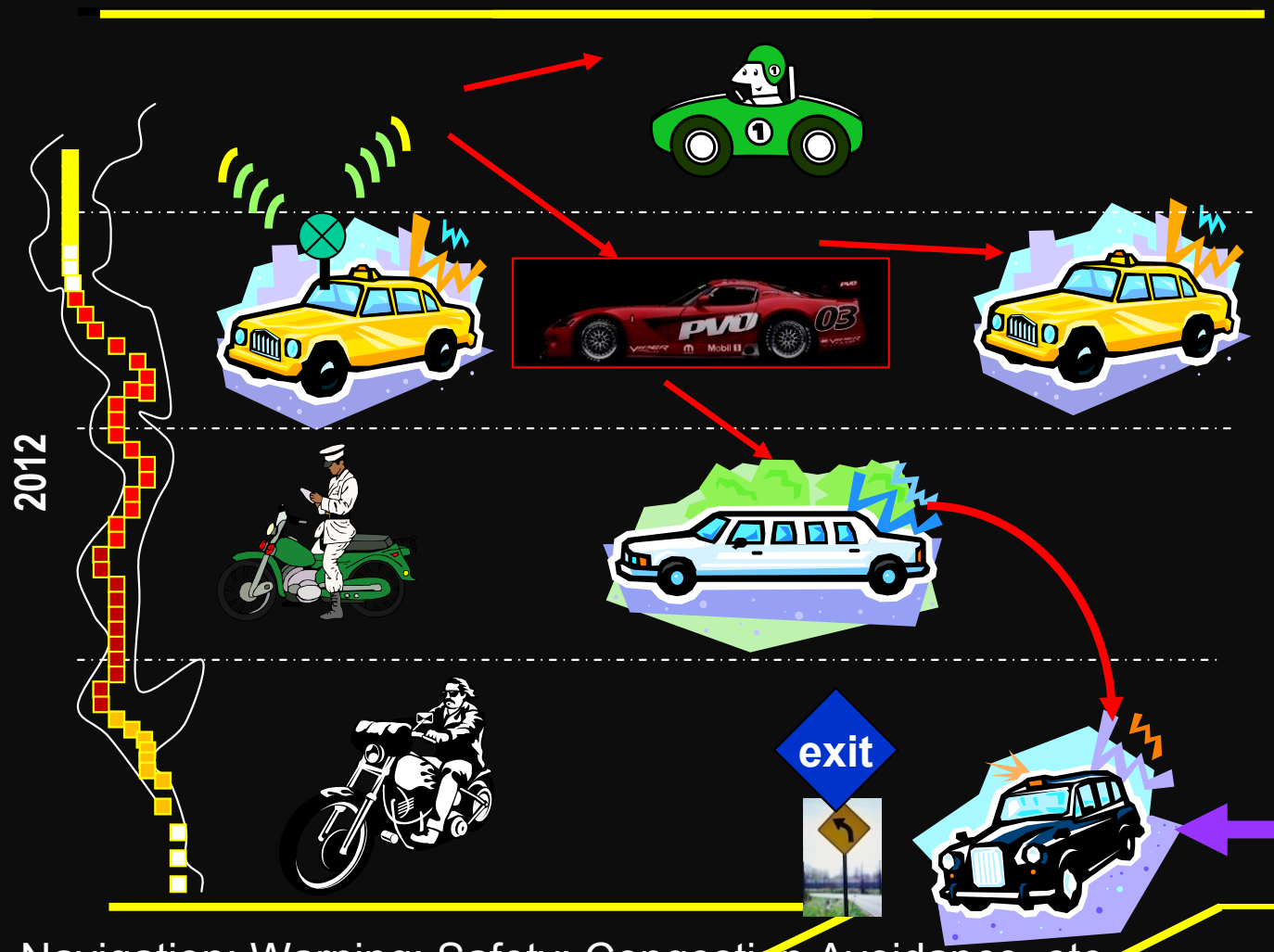
ITS mobile comms-enabled car communities

CAR COMMUNITIES

1. "Get-in-touch" on the road
2. Fulfill common mission
3. Use ad hoc comms
4. Instant networking

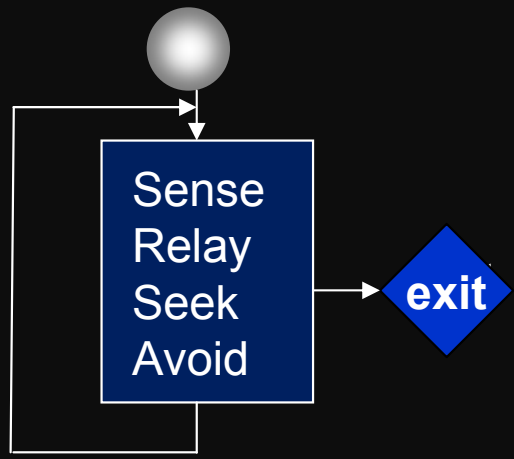


HARZARD NOTIFICATION & TRAFFIC CONTROL



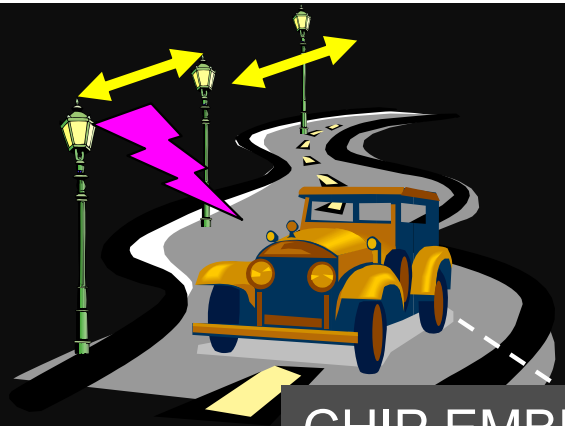
TRAFFIC FLOW & CONGESTION CONTROL

Inform cars ahead/back
Seek alternate routes
Avoid further congestion
- Call for HELP



Car informed and seek nearest exit to avoid congestion

Navigation; Warning; Safety; Congestion Avoidance, etc

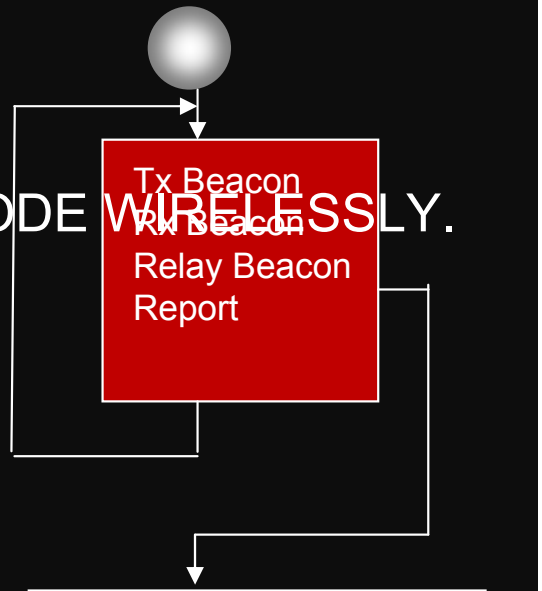


LAW ENFORCEMENT USING MULTIHOP COMMUNICATIONS

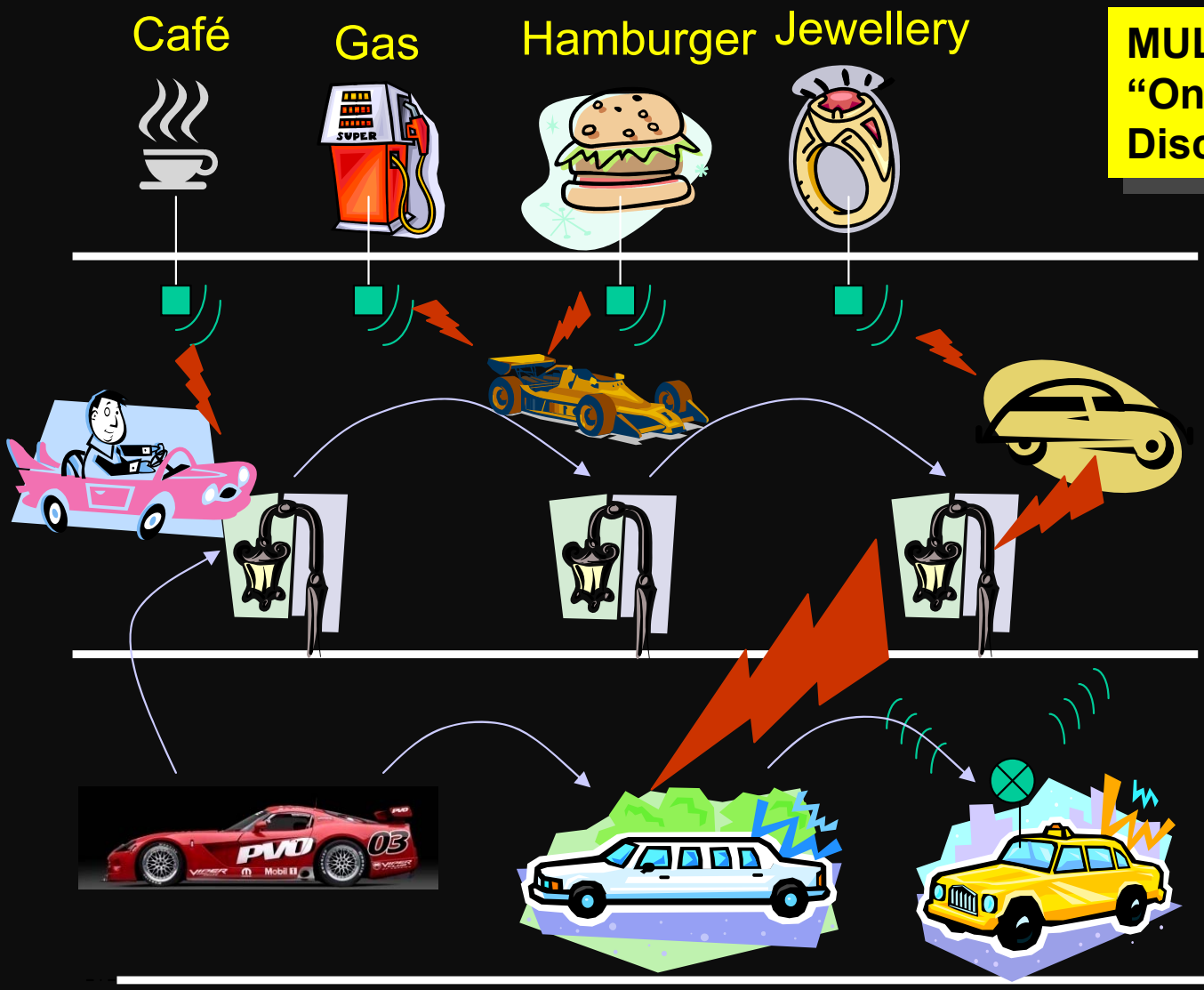
CHIP EMBEDDED INTO CAR. EMITS SECRET CODE WIRELESSLY.

STOLEN CARS OR RUN-AWAY CRIMINALS

POLICE



Police tracks down location of stolen car to nearest Lamp-post and on specific street and city



MULTI-HOP Wireless
"On-The-Road Service"
Discovery/ Shopping Network

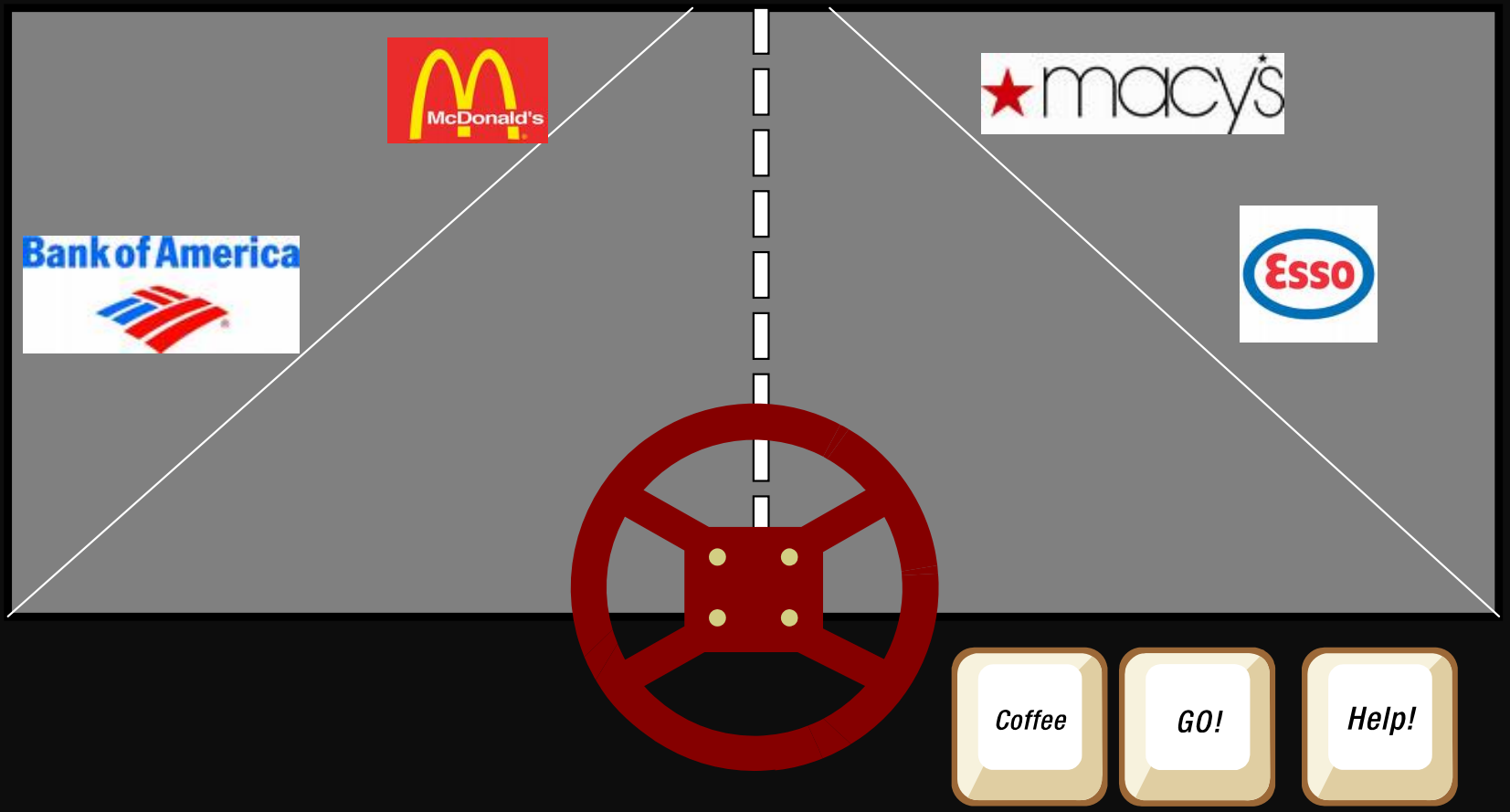
Tx Beacon
Rx Beacon
Build
Intelligence

BLOS OTR Shopping
Resource Locator
Trip Planning

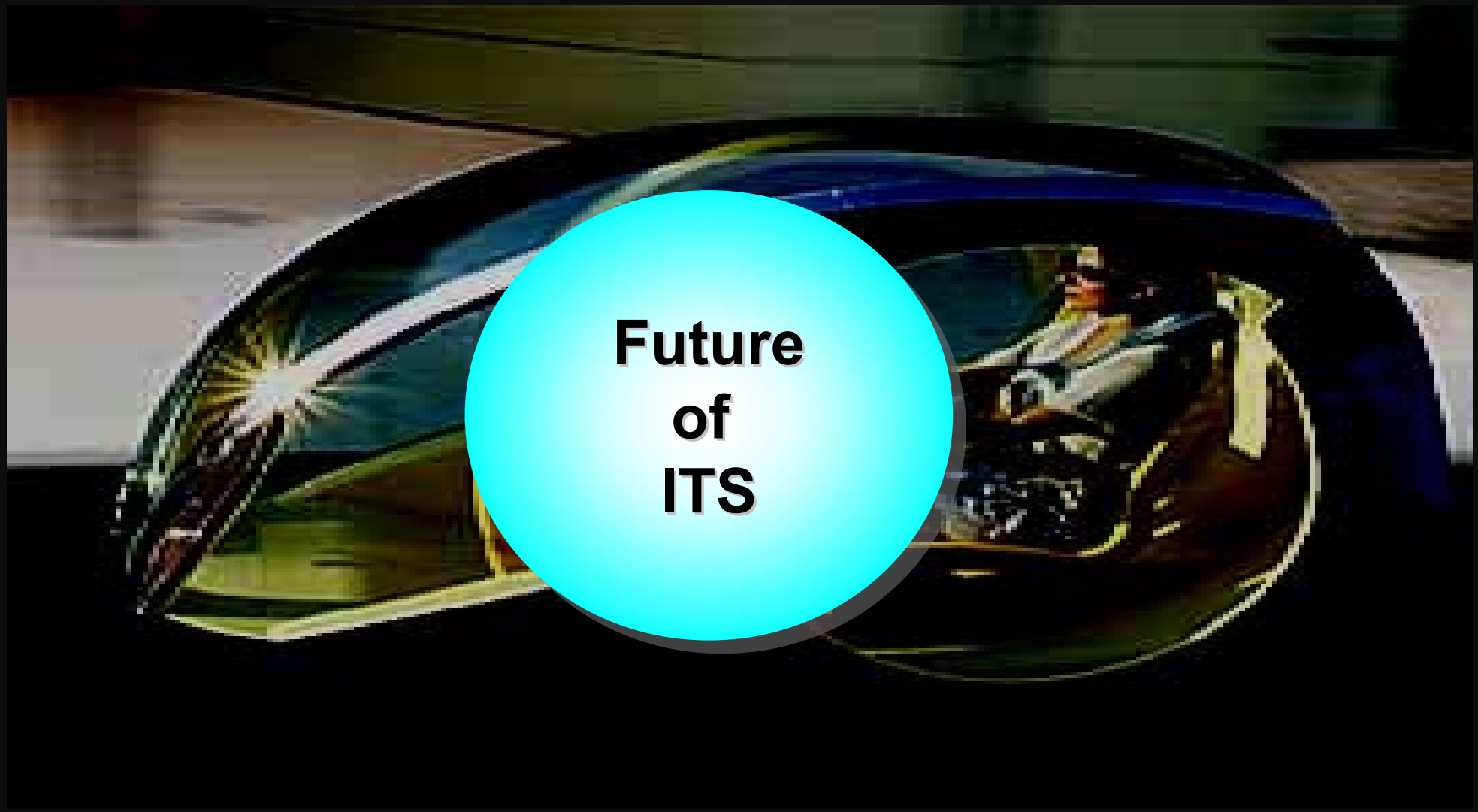
Navigation; Warning; Safety; Congestion Avoidance, Shopping, etc

Continue: OTR Retail, Shopping, Service Discovery

Display (totally different driving experience! Not afraid of commuting to new areas)



Voice Query
Voice Recognition
Eye Motion
Head Motion


Future
of
ITS

- Future Cars that "talk"

ITS – The comms-enabled Driver?

Move "indicators" outside the

▶ BASICALLY, WE WANT

- Cars that "**talk**"
- Cars that "**warn**"
- Cars that "**sense**"
- Cars that "**navigat**
- Cars that "**locate/find**"
- Cars that .."**you name it!**"

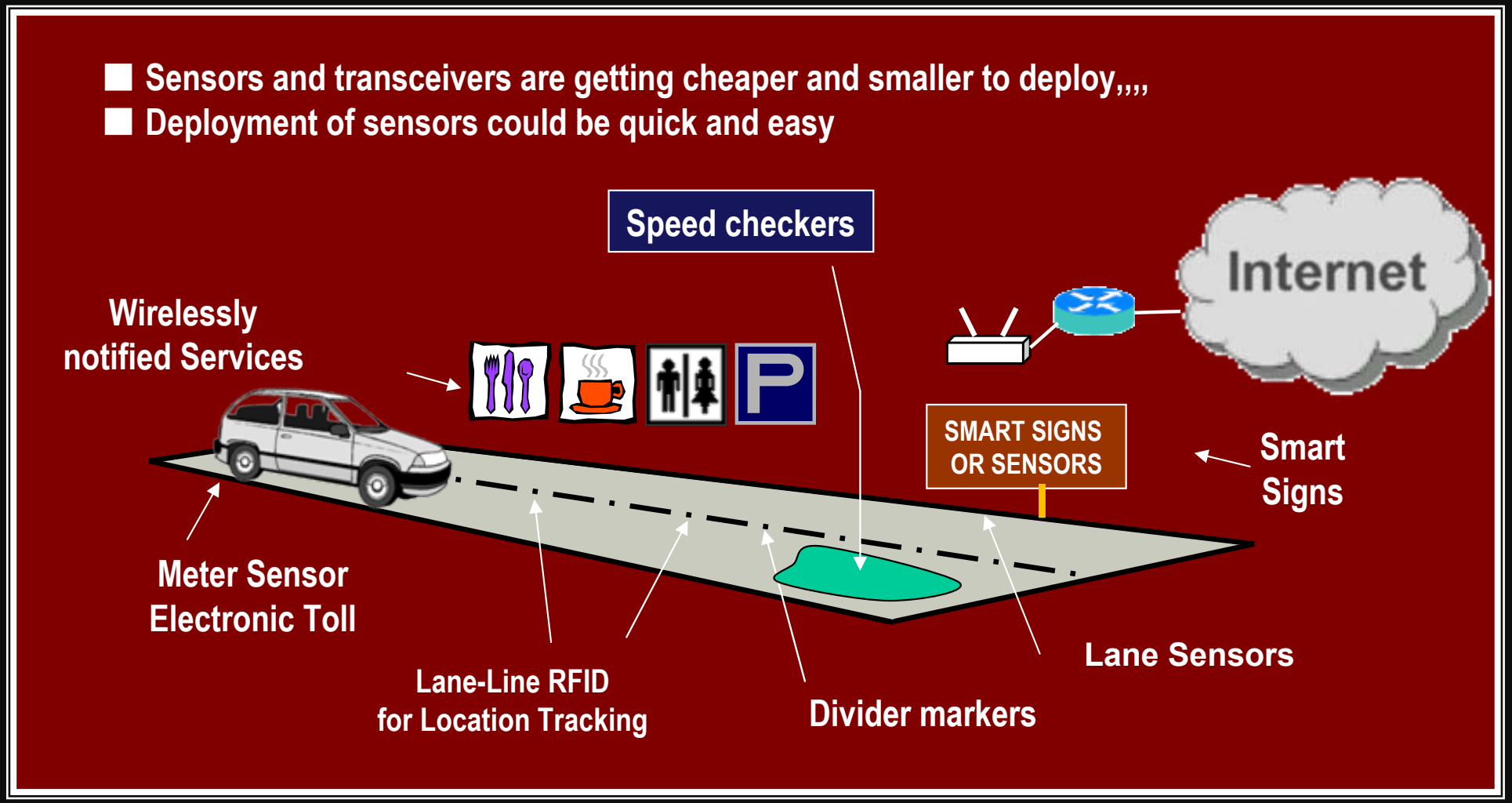
- **Replace signs with wireless sensors and notifiers!!**

No worries about missing a sign

Nanosensors
Temperature sensors
Pressure sensors
Sensors that warn + talk

Programmable Notifiers
Emits Messages periodically
Possibly propagated car2car

- **Make Roads "Active"!**



- **Bigger Goals!**

Ubiquitous ITS

Ubiquitous ITS

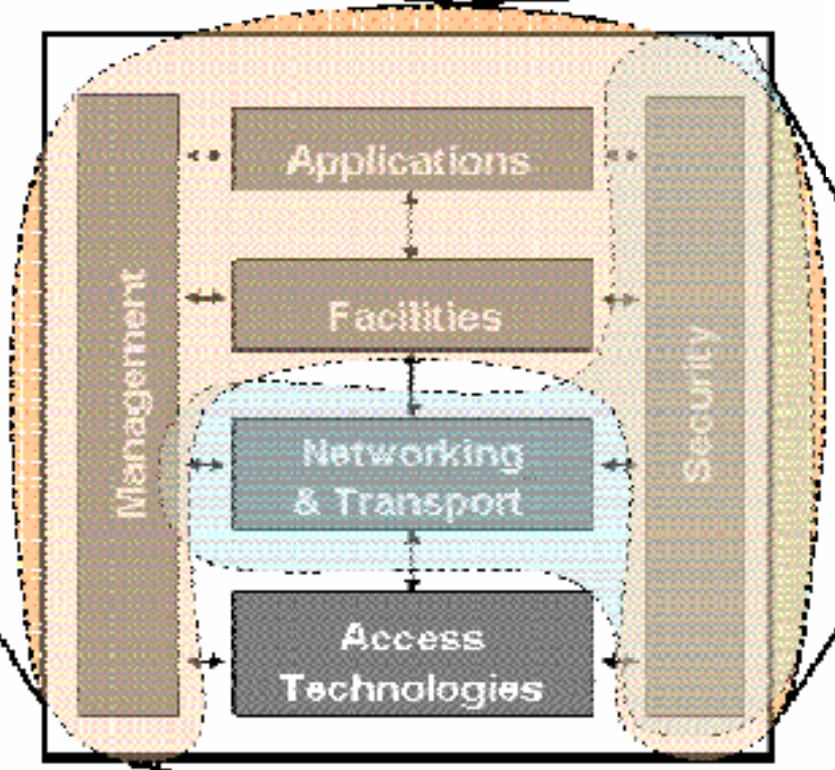
GOALS

- Zero Traffic Fatality Society
- Zero Congestion Society = Cleaner Environment
- Zero Transportation Stress Society
- Fully Connected Society
- Enriched Driving Experience

Future Applications of u-ITS

IR

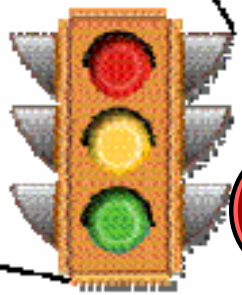
1.Truck Weighing
2.Congestion Zone Pricing
3. Music on Road
etc



IV

1. Localized police
2. Localized medical
3. Real-time NAVI
4. Car social network

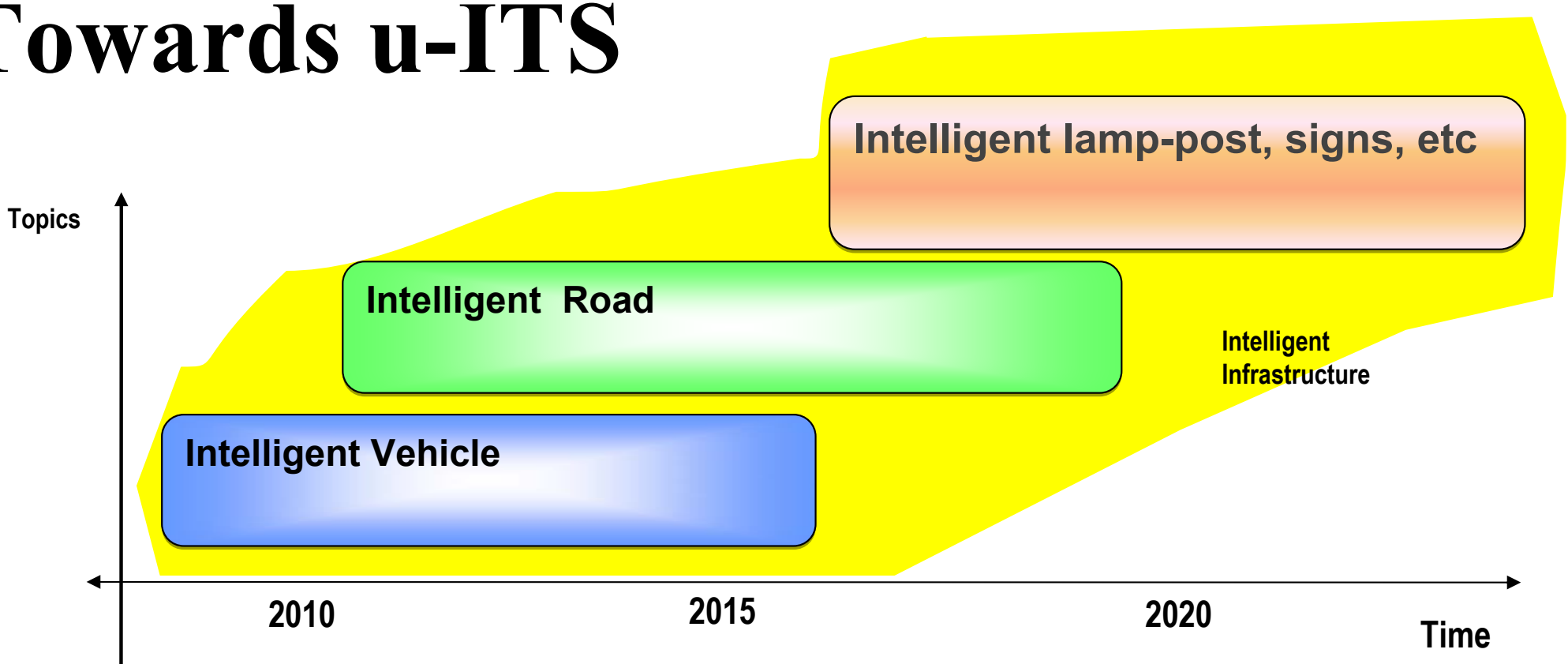
FUTURE APPLICATIONS

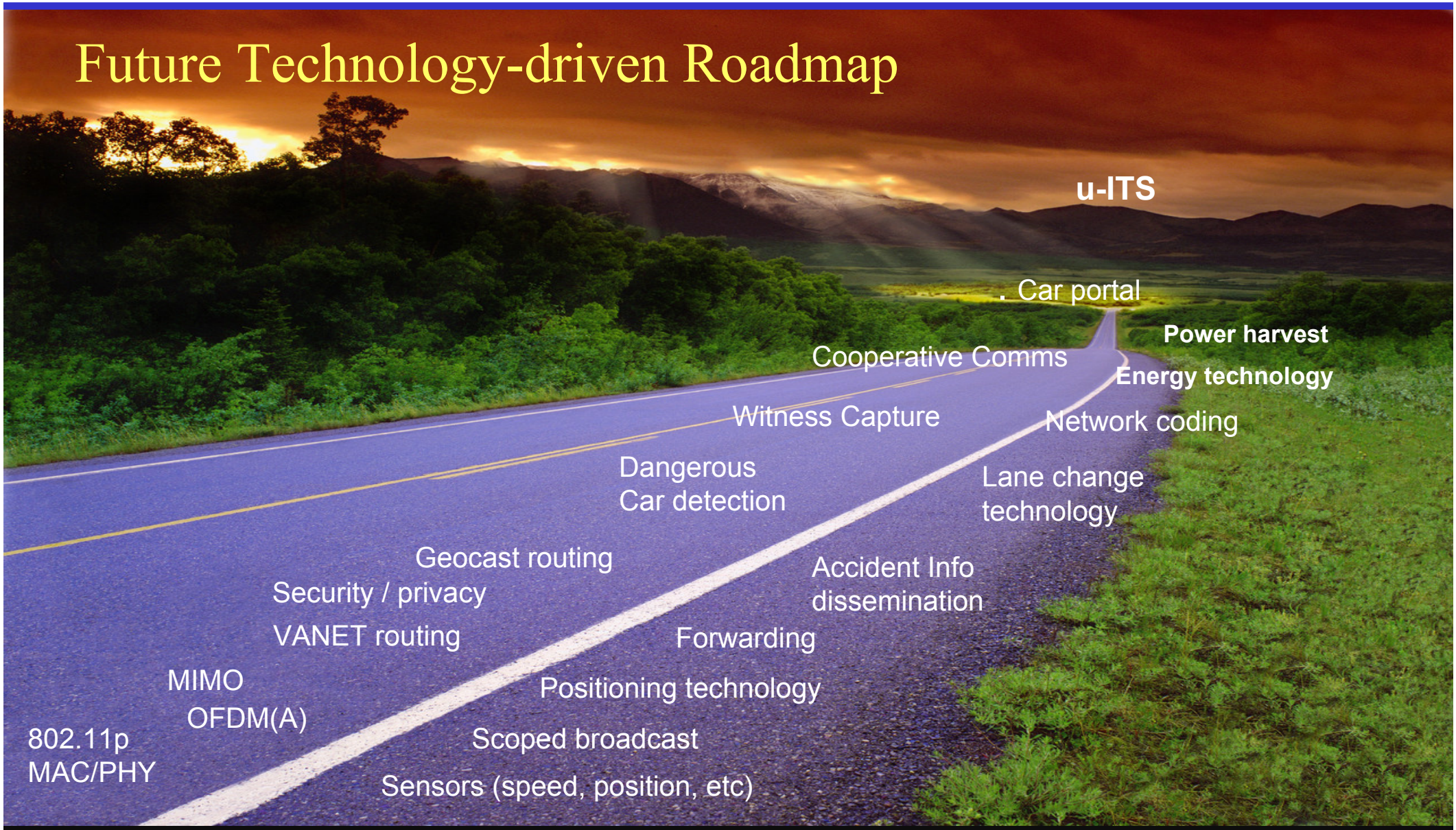


IP

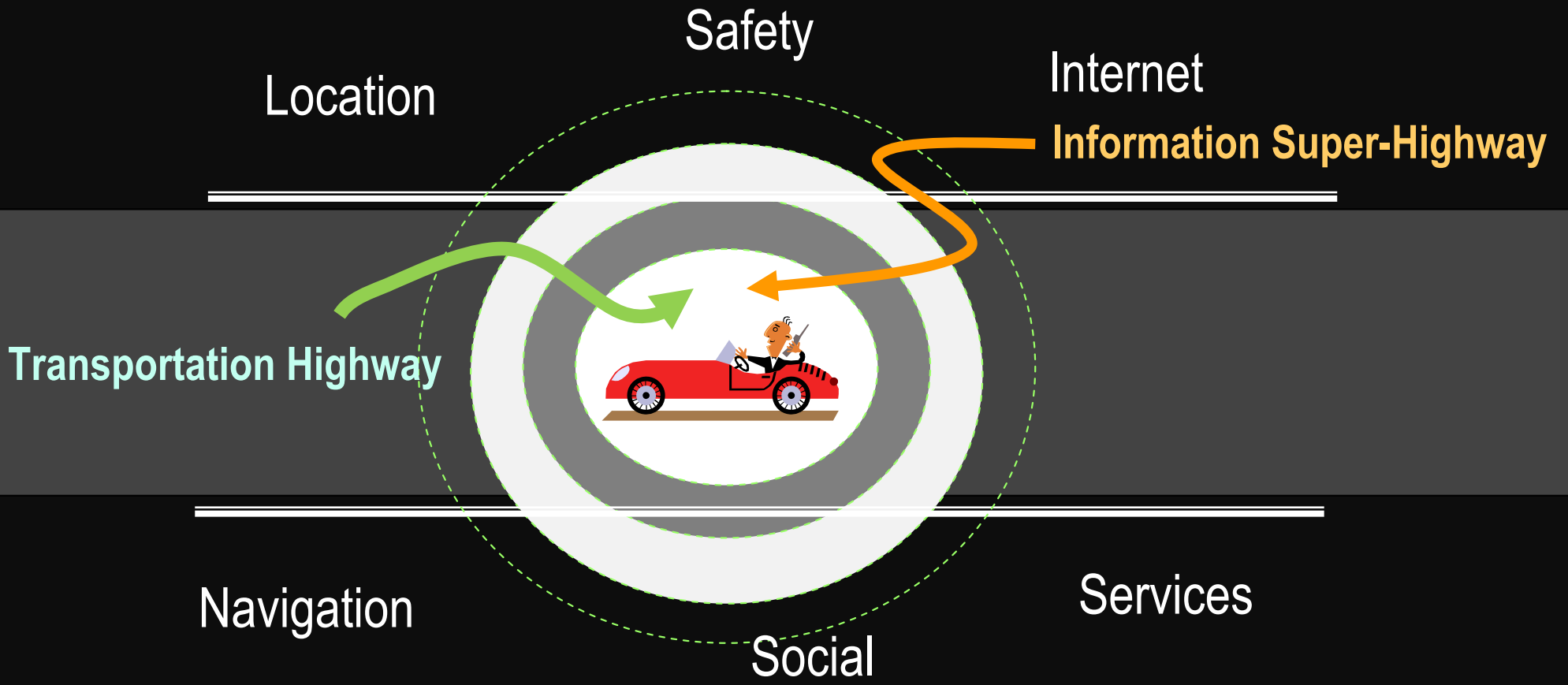
Wireless Signs
Intelligent Traffic Control

Towards u-ITS




Future Technology-driven Roadmap
u-ITS
. Car portal
Power harvest
Energy technology
Cooperative Comms
Witness Capture
Network coding
Dangerous
Car detection
Lane change
technology
Geocast routing
Security / privacy
Accident Info
dissemination
VANET routing
Forwarding
MIMO
Positioning technology
OFDM(A)
802.11p
MAC/PHY
Scoped broadcast
Sensors (speed, position, etc)

- So, the Future provides a completely different driving experience !



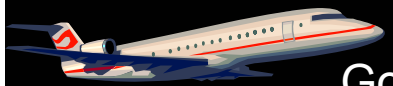
In Summary,,,,,,,,,,,

- Vehicle as Transporters
- Vehicle as Polluters (joke,,)
- Vehicle as Sensors
- Vehicle as Tax/Toll-Contributors
- Vehicle as Message Relays
- Vehicle as Communicators
- Vehicle as Internet Node, etc you name it!

Conclusion

- Plenty of Research for us to do!!
- Good n Vast Market Potential
- On-the-Road Technologies needed.
- Our Destination: An
  - * **information-driven,**
  - * **knowledge-based,**
  - * **wirelessly-enabled superhighway**

  (drive, shop, navigate, find, etc)



Goodbye!