Challenges in Urban and Mobility Systems and Networks

Moderator

Li-Chun Wang, National Chiao Tung University, Taiwan

Panelists

Heena Rathore, Hiller Measurements, USA

Eugen Borcoci, University POLITEHNICA Bucharest, Romania

Fehmi Jaafar, Centre de recherche informatique de Montréal, Canada

Leonard Petnga, University of Alabama in Huntsville, USA

Topic	Speaker
Blockchain technology to enhance safety aspects of self-driving cars	Heena Rathore
Novel technologies supporting mobile V2X vehicular communications	Eugen Borcoci
Cyber-security Challenges in Smart Cities	Fehmi Jaafar
Towards Graph Foundations for Addressing Urban Mobility Challenges	Leonard Petnga
AI-empowered Future Mobile Systems: A Cellular Architecture Perspective	Li-Chun Wang

Heena Rathore (1/2)

- Dr Heena Rathore is lead data scientist and program manager at Hiller Measurements Inc, Austin Texas, USA. Previously, Dr Rathore was a post doctorate researcher for US-Qatar Joint Collaborative Project between University of Idaho, USA, Temple University, USA and Qatar University, Qatar in 2017. She also worked as a visiting research scholar for Wichita State University, USA in 2016. She received her Ph.D. (with distinction) in Computer Science and Engineering Department while she was a Tata Consultancy Services Research Scholar at Indian Institute of Technology, India in 2015. She received her bachelor in Computer Science Engineering from College of Technology and Engineering in 2010 with Honors.
- She has also worked professionally as Design Executive with Phosphate India Private Limited, India and academically as Guest Lecturer at UT Austin, USA and Assistant Professor with SS College of Engineering, India.

Heena Rathore (2/2)

- She has been the winner of number of prestigious awards including Graphical System Design Achievement Awards held by National Instruments in 2013. She has published more than 25 papers in peer reviewed conferences and journal papers in her field and is the sole author of, "Mapping Biological Systems to Network Systems" published by Springer. Dr Rathore was also featured on TedX, Qatar held by TedXAlDafnaEd in Qatar.
- She has been invited to chair number of sessions and is a TPC member of number of peer reviewed conferences. Besides this, she has been the reviewer of IEEE ICC, IEEE Access, IET Journal of Engineering, IEEE IPCCC, IEEE CEEC, Elsevier Ocean Engineering Journal, IEEE PIMRC, Journal of Decision Systems, AsiaCCS, IEEE ICCCN, Wireless Communications and Mobile Computing, IEEE symposium on Multimedia, IEEE ANTS, IEEE SmartGrid Comm, BDCloud.
- Her research interests include deep learning, machine learning, security, distributed systems, wireless networks, biologically inspired systems and software defined networking.

Eugen Borcoci (1/2)

- He graduated from Polytechnic Institute of Bucharest, Electronics and Telecommunications Faculty, Romania and then from University of Bucharest, Faculty of Mathematics and Informatics, Romania. He obtained his Ph.D degree in telecommunications at Polytechnic Institute of Bucharest in 1980. Since 1995, he is professor at University Politehnica Bucharest (UPB), Electronics, Telecommunications and Information Technology Faculty, Telecommunications Department, (www.elcom.pub.ro).
- His expertise, teaching activities and research have been oriented to specific domains of telecommunications systems and networks, computer and integrated networks and services. Specific areas of expertise and interest have been: layered multiple-plane architectures for integrated networks, broadband networking technologies, communication protocols (specification, validation, performance evaluation and implementation), signaling systems and applications. In the last decade, his research area has been focused in Quality of Services assurance and management over multiple domains networks and multicast and multimedia flows transportation over IP networks and heterogeneous access. Recently, his research interest is on new wireless/IP technologies, e.g 802.16/WiMAX, and wireless mesh networks. He has published 5 books, 4 textbooks and over 130 scientific or technical papers and scientific reports.

Eugen Borcoci (2/2)

- Eugen Borcoci has been long time and currently is involved in research and development in the above mentioned areas. He has been UPB team leader in several European Commission funded joint IST research projects: COP62, KIT, MOICANE, Euro-Next Generation Internet Network of Excellence (EuroNGI, 2004-2006, www.eurongi.org) Euro-Future Generation Internet (EuroFGI, 2006-2008, www.eurongi.org) ENTHRONE (2004-2008, www.enthrone.org), WEIRD (2006-2008, www.ist-weird.eu) SMART-Net (2008-2011, www.ict-smartnet.eu), etc. Also he participated as a team leader or team member in a lot of national R&D projects, (over 30).
- He was member of several Int'l Conferences Committees: PSTV'95, CFIP'96 - 99, IEEE ICT 2001, 2002, Eurasia ICT 2002, FORTE 2003, MoMM2004, NGI 2005-2008, AICT 2005-2008, COMM 2002-2008, ICWMC 2007-2008, CTRQ 2008, etc. In the last four years he was an active person to promote and contribute to IARIA Conferences, both as an author contributor (papers, tutorials) and some specific organizational activities. He contributed also as a scientific reviewer to several national and international journals in the field.
- Eugen Borcoci is member of IEEE Communication Society. He is also member of the Technical Sciences Academy of Romania. He obtained several national awards for research activities in the above mentioned fields.

Fehmi Jaafar

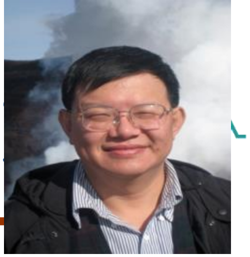
- Dr. Fehmi Jaafar holds a Ph.D. from Montreal University in Quebec after receiving a software engineering Master degree with honours from University of Tunis in Tunisia. He taught a variety of Information System and Information Security courses in both French and English in three Canadian universities (Concordia University of Edmonton, University of Montreal and Polytechnique Montreal) and a training course at Ubitrak Inc.
- Dr. Fehmi Jaafar is a member of IEEE. He speaks fluent English, French and Arabic. He had several years of industry experience in Canada and Africa in the areas of software engineering, Computer Security, Web and Mobile Computing, and Business Process Management.
- Dr. Jaafar's research interests include:

Software Security Assurance	Cyber Security
Mining Software Repositories	Big Data
Fault Proneness	Cloud Computing
Software Reliability	Web and Mobile Computing

Leonard Petnga

- Dr Petnga is an Assistant Professor of Systems Engineering at the University of Alabama, Huntsville. He holds a Masters in Systems Engineering and PhD in Civil Systems from the University of Maryland, College Park. He is a former Cyber-Physical Systems (CPS) Scholar at the US National Institute of Standards and Technology (NIST) and Postdoctoral Fellow at the US Army Research Laboratory (ARL) and the Institute for Systems Research (ISR) at the University of Maryland, College Park.
- He is a former Cyber-Physical Systems (CPS) Scholar in the Systems Integration Division (SID) at the National Institute of Standards and Technology (NIST). In 2013, he won the Best Paper Award at the 11th Annual Conference on Systems Engineering Research (CSER2013).
- His research focuses on knowledge structures for MBSE and integration of complex systems with an emphasis on CPS. His work involves the development of procedures for reasoning and integration of system behavior and structure across domains with applications in transportation (air, ground, water), aeronautic and Internet of Things (IoT).

Li-Chun Wang



- Li-Chun Wang (M'96 -- SM'06 -- F'11) received Ph. D. degree from the Georgia Institute of Technology, Atlanta, in 1996. From 1996 to 2000, he was with AT&T Laboratories, where he was a Senior Technical Staff Member in the Wireless Communications Research Department. Since August 2000, he has joined the Department of Electrical and Computer Engineering of National Chiao Tung University in Taiwan and is jointly appointed by Department of Computer Science and Information Engineering of the same university.
- Dr. Wang was elected to the IEEE Fellow in 2011 for his contributions to cellular architectures and radio resource management in wireless networks. He won the Distinguished Research Award of National Science Council, Taiwan (2012). He was the co-recipients of IEEE Communications Society Asia-Pacific Board Best Award (2015), Y. Z. Hsu Scientific Paper Award (2013), and IEEE Jack Neubauer Best Paper Award (1997).
- His current research interests are in the areas of software-defined mobile networks, heterogeneous networks, and data-driven intelligent wireless communications. He holds 19 US patents, and have published over 200 journal and conference papers, and co-edited a book, “Key Technologies for 5G Wireless Systems,” (Cambridge University Press 2017).

Blockchain and Self Driving Cars

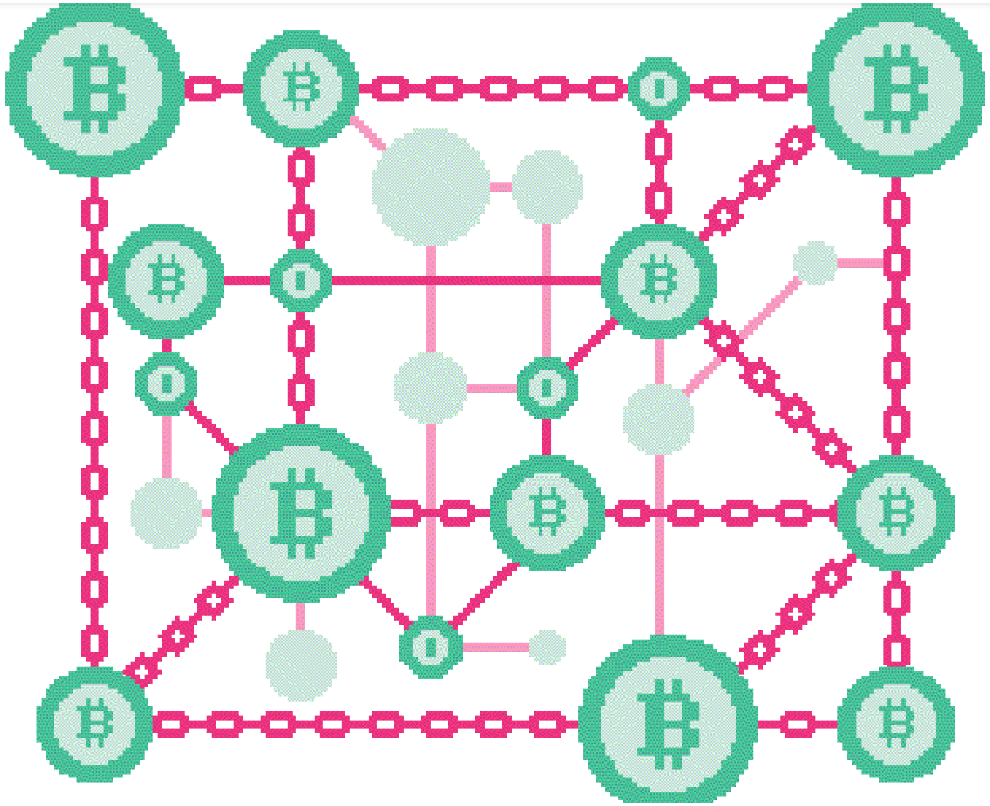
DR. HEENA RATHORE

DATA SCIENTIST

HILLER MEASUREMENTS, USA

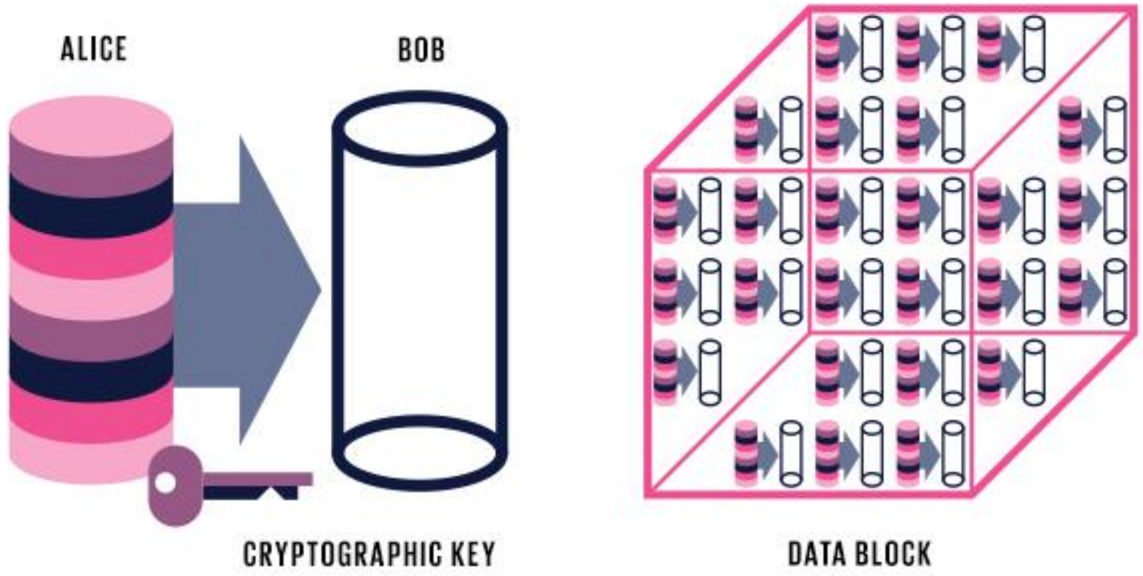
Blockchain: The Technology behind bitcoins

- Bitcoins developed as an alternative to currency, after the Great Recession of 2009
- A group of anonymous hackers, with alias of Satoshi Nakamoto, responsible for writing the first set of code
- Has taken off since then, with very few (one confirmed) reports of successful hacking
- Researchers are now looking at other places where this technology can be used
- Active area of research in Education, Health, Self-driving cars and numerous other applications



How Blockchains work

- Key questions: Who adds the next chain of data and how is it added?
- Two strategies prevail: proof of work and proof of stake.
- Alice tells the Bitcoin network she wants to pay Bob. Uses a cryptographic key to digitally sign off on the transaction, providing proof that she owns these coins.
- Network operators, called miners or block signers, scoop up a bunch of transactions to validate them.
- Check that the digital signatures are correct and that there are enough coins for the requested transactions.
- Put all the new transactions into a new data block to be added to the blockchain.



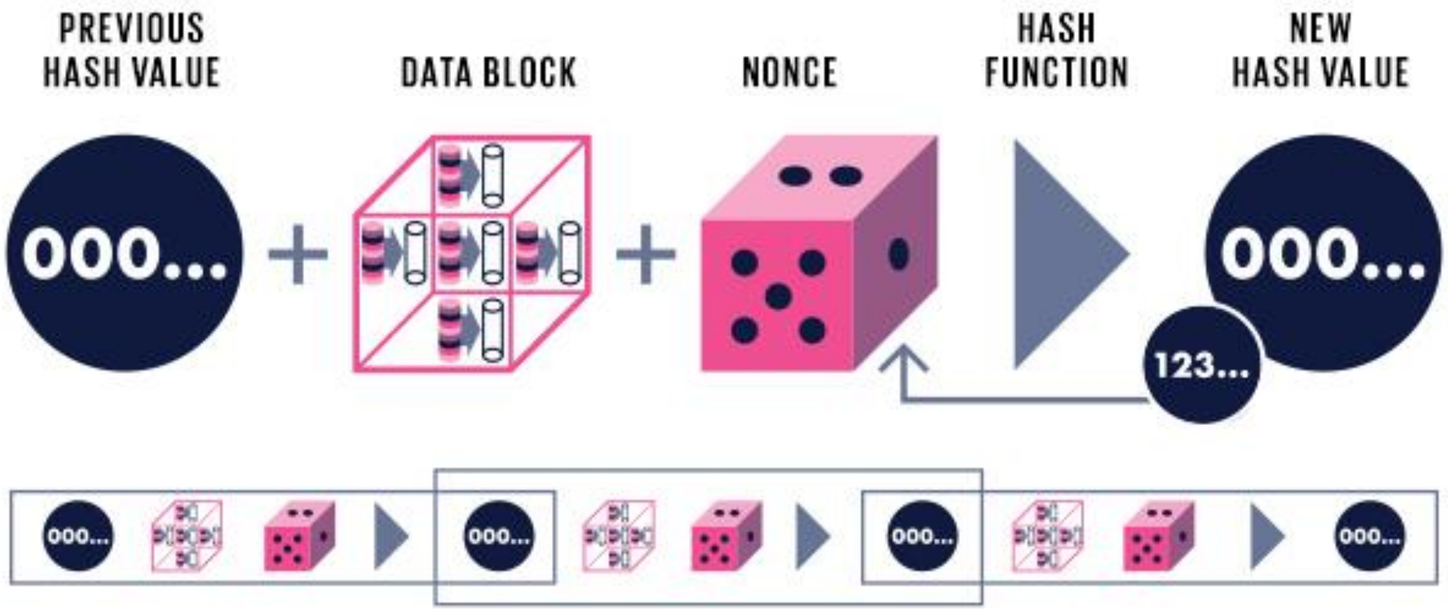
Source: IEEE Spectrum

Blockchain Vocabulary

- **Blockchain:** A shared database that grows only by appending new data, authenticates users with strong cryptography, and leverages economic incentives to encourage mistrustful strangers to manage and secure updates.
- **Proof of stake**: A mechanism for allocating the right to add new blocks of data to a public blockchain. Participants (Block signers) gain the right to add new blocks by proving they own cryptocurrency.
- **Proof of work**: A mechanism for allocating the right to add new blocks of data to a public blockchain. Participants (miners) gain the right to add new blocks by repeatedly running a hash function.
- **Public blockchain**: A blockchain that is open for anyone to look at and to add new blocks to. Certain resources (computing power, possession of the native cryptocurrency) may be required to add new blocks, but anyone has the right to do so. Ethereum is an example of public blockchain
- **Permissioned ledger**: A database, inspired by blockchain technology, that restricts access to reading, writing, or both to a set of known actors. It's also called a private blockchain.
- **Oracle**: An entity that records data about real-world events—such as the ambient temperature or the outcome of a presidential election—on a blockchain. It serves as a reference for smart contracts.
- **Smart contracts**: Software-based agreements deployed in systems capable of automatically executing and enforcing the terms of the contracts

Proof of Work

Create a hash from a particular set of data and a nonce.

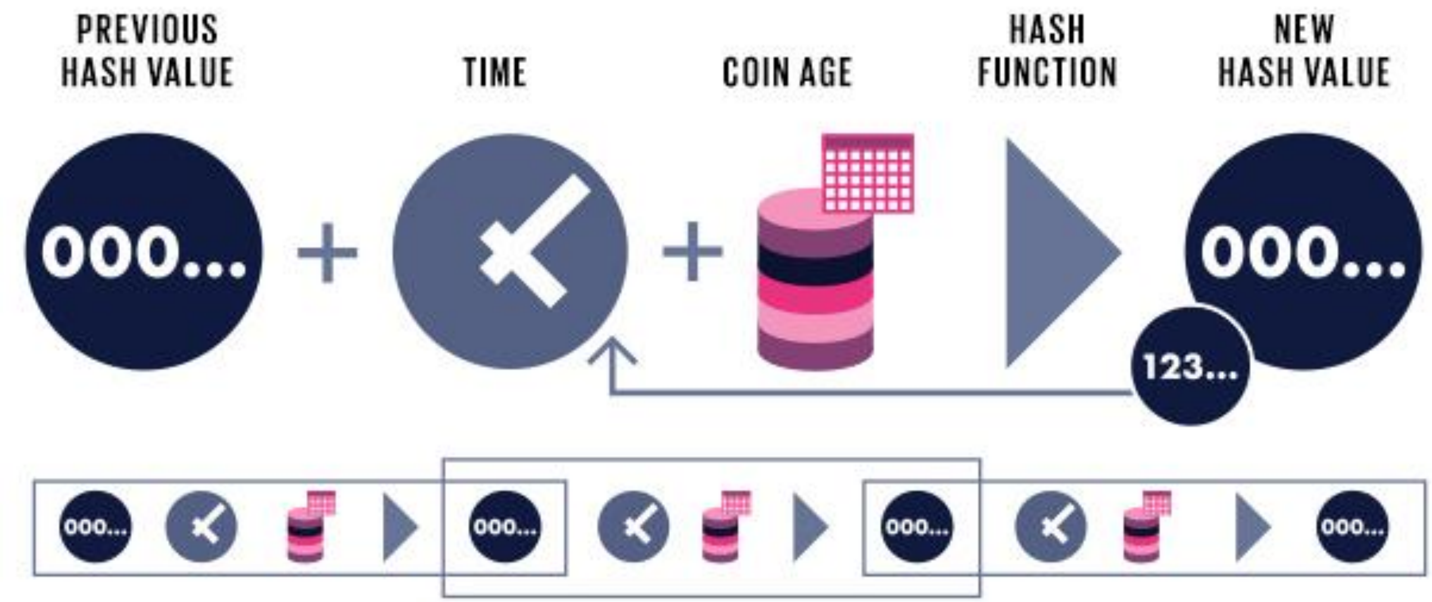


If the hash does not begin with a particular number of zeros, the hash function is rerun using a new random number (the nonce).

Including previous blocks in every new hash compounds the difficulty of tampering with older transactions.

Proof of Stake

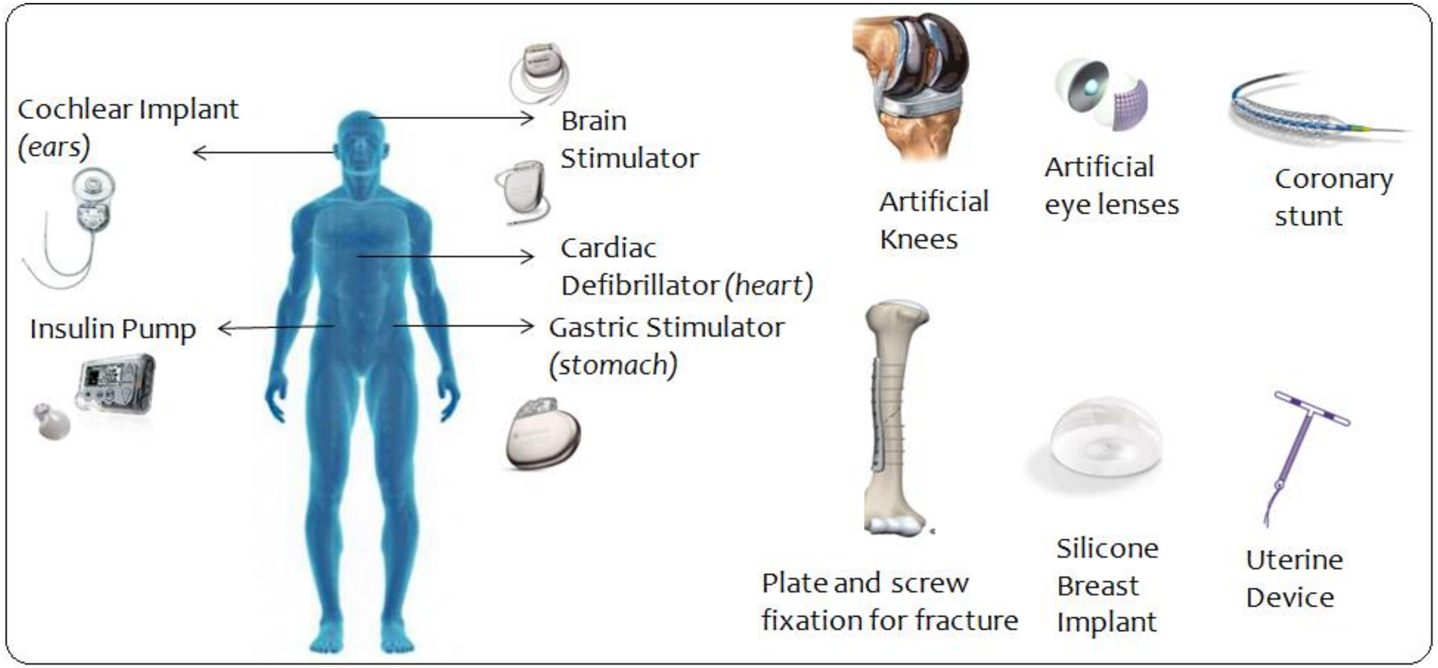
Create a hash from a set of data that includes coin age—a number indicating an amount of coins owned by the signer and how long they've owned them.



If the hash does not begin with a particular number of zeros, the function is rerun using a new time stamp.

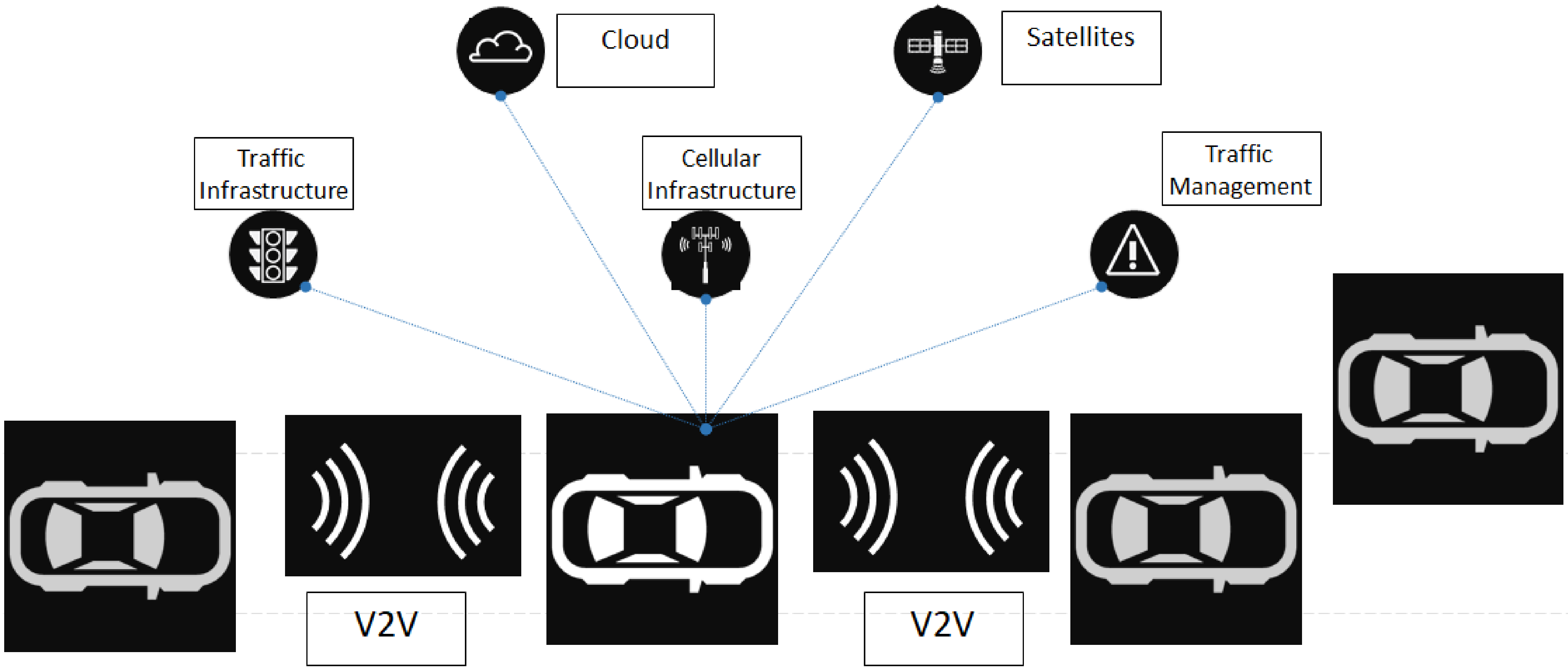
Blockchains to address Security Concerns in Wireless Medical Devices

Implantable Medical Devices(IMDs) can be defined as an instrument which is medically injected inside the body of human beings to diagnose, prevent, monitor, treat, control, cure or alleviate diseases. These devices are placed inside the human bodies to analyze, monitor and respond to treat chronic medical diseases.



Rathore, H., Al-Ali, A., Mohamed, A., Du, X. and Guizani, M., 2017, December. DLRT: Deep Learning Approach for Reliable Diabetic Treatment. In *GLOBECOM 2017-2017 IEEE Global Communications Conference* (pp. 1-6). IEEE.
Rathore, H., Mohamed, A., Al-Ali, A., Du, X. and Guizani, M., 2017, June. A review of security challenges, attacks and resolutions for wireless medical devices. In Wireless Communications and Mobile Computing Conference (IWCMC), 2017 13th International (pp. 1495-1501). IEEE.

Self Driving Cars (A Mobile Network)



Blockchain players in self-driving cars

- **Blockchain**: A shared database of road conditions and software updates, which grows by appending new data. Authenticates users with strong cryptographic keys and leverages economic incentives to encourage mistrustful participants
- **Block signers/Miners**: Autonomous vehicles play the role of block signers
- **Oracle**: Sensors in the car which can capture information from the surroundings. Likewise, base stations and communications equipped infrastructure can also act as Oracles

Permissioned ledger: Information kept on secured base station

Proof of stake: Driving record, insurance standing

Proof of work: Demonstrated capabilities of self-driving cars in terms of sensing, communication and data analytics

Public blockchain: Information distributed across multiple storage devices

Smart Contracts: A request for information of the road and driving conditions, issued by either a traditional car or self-driving car

Blockchain applications for self-driving cars

Self-Driving Cars

- Can they be used to provide secure V2V and V2X communication?
- Can traditional cars use the technology to safely rely on data from self-driving cars?
- Can blockchains be used to safely add currency to self-driving cars for gas and service?
- Can cars maintain a database of authorized software and firmware updates using blockchain?

Thank You ☺

CRIM

CENTRE DE
RECHERCHE INFORMATIQUE
DE MONTRÉAL

CHALLENGES IN URBAN AND MOBILITY SYSTEMS AND NETWORKS

Fehmi Jaafar, CRIM

PRINCIPAL PARTENAIRE FINANCIER

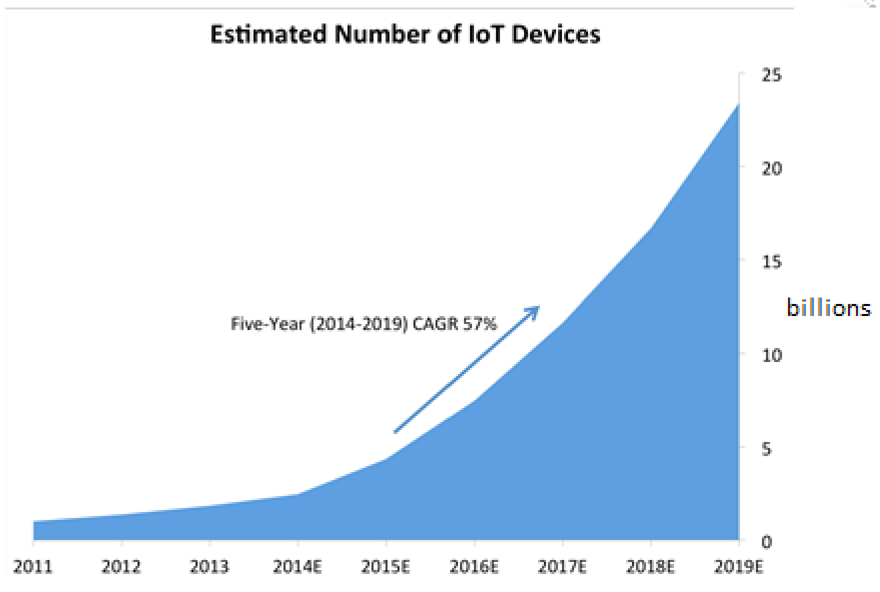
Économie, Science et Innovation
Québec

CRIM

The Computer Research Institute of Montréal is an applied research and expertise centre in information technology, dedicated to making organizations more effective and competitive through the development of innovative technology and the transfer of leading edge know-how, while contributing to scientific advancement.

1. SMART CITIES AND IOT

1. IOT: A HUGE NUMEBR



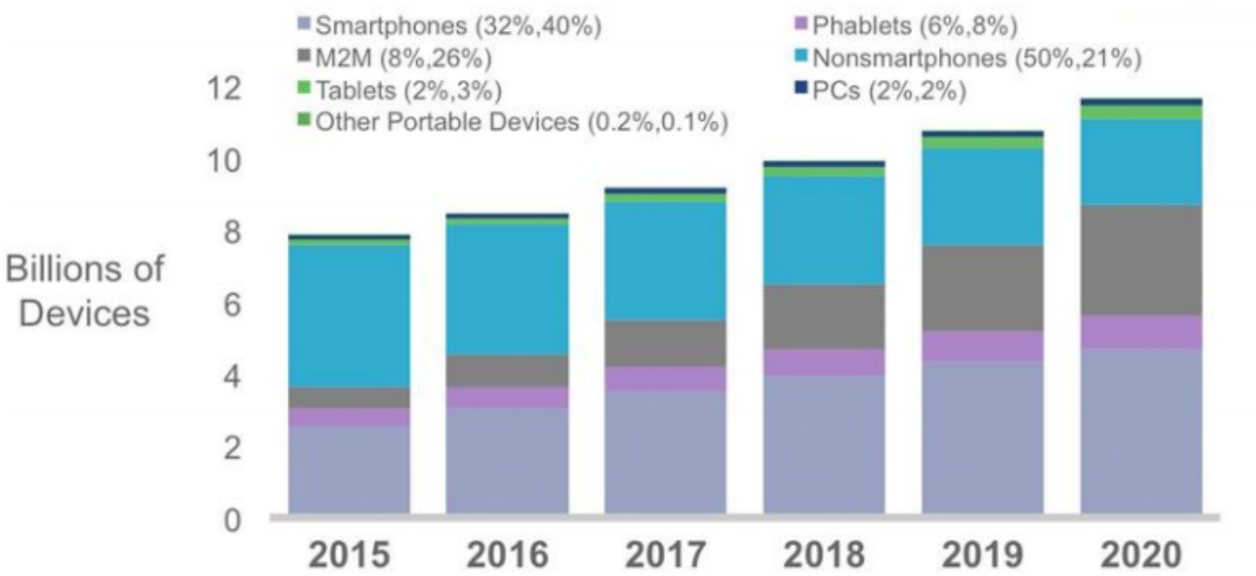
Source : Business Insider

Table 1: IoT Units Installed Base by Category (Millions of Units)

Category	2016	2017	2018	2020
Consumer	3,963.0	5,244.3	7,036.3	12,863.0
Business: Cross-Industry	1,102.1	1,501.0	2,132.6	4,381.4
Business: Vertical-Specific	1,316.6	1,635.4	2,027.7	3,171.0
Grand Total	**6,381.8**	**8,380.6**	**11,196.6**	**20,415.4**

Source: Gartner (January 2017)

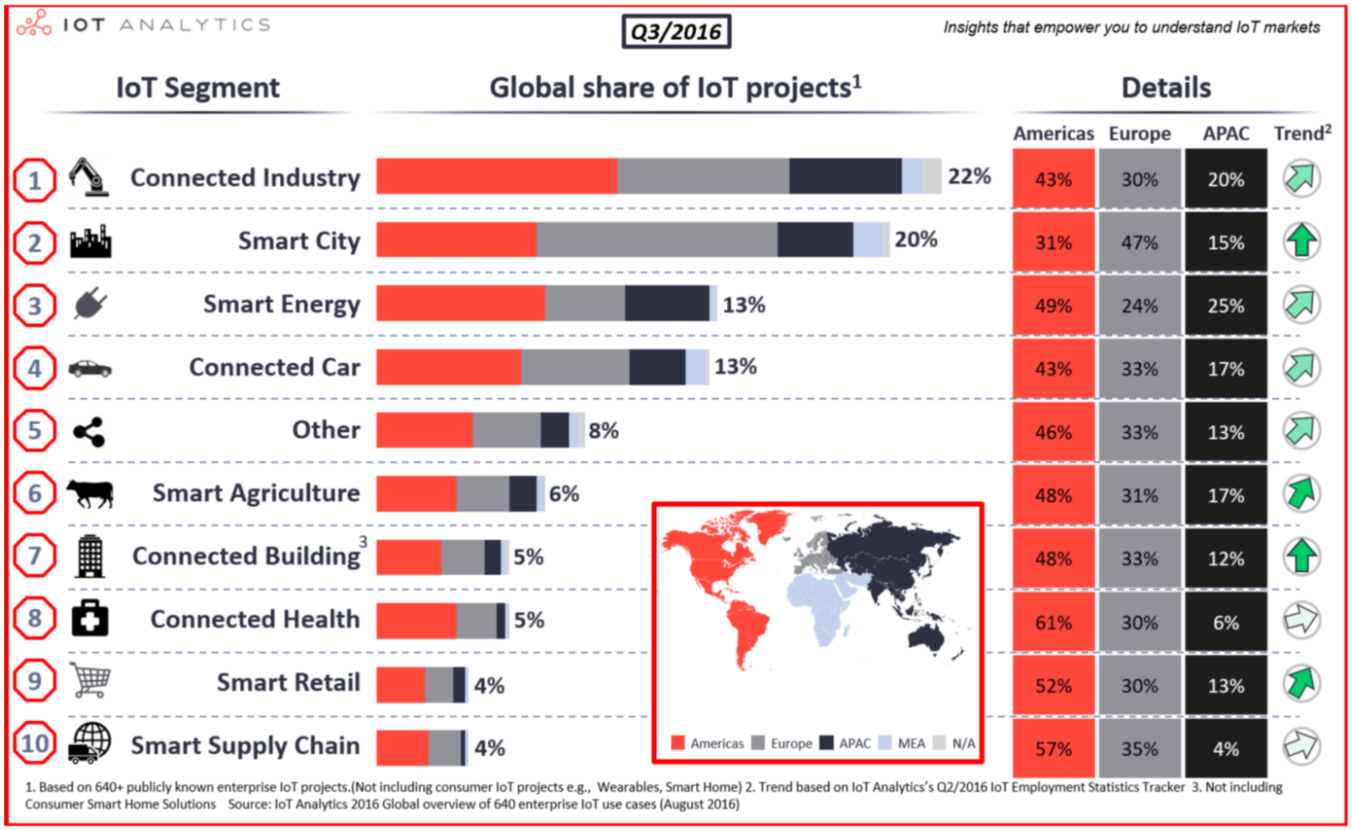
LIMITED RESSOURCES



Source: Cisco VNI Mobile, 2016

« By 2021, there will be 3.3 billion M2M connections (e.g., GPS systems in cars, asset tracking systems in shipping and manufacturing sectors, or medical applications). » Cisco VNI Mobile, 2016.

DIVERSIFIED SEGMENTS AND CHALLENGES



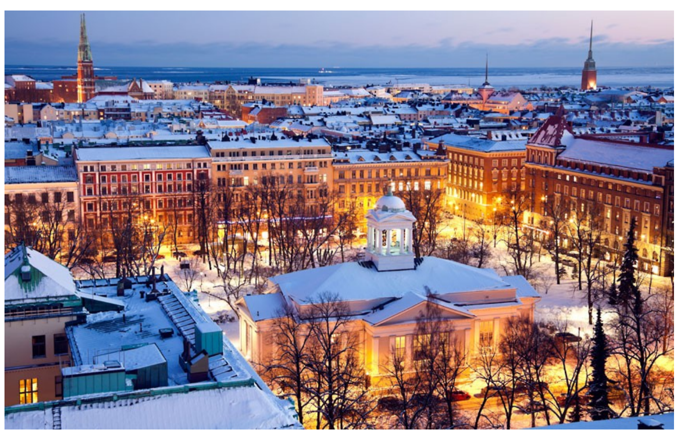
SMART CITIES MAY BE THE DEATH OF PRIVACY AS WE KNOW IT

SECURITY CHALLENGES

- Botnet Mirai
- IoT Reaper

SECURITY CHALLENGES

A DISTRIBUTED DENIAL OF SERVICE (**DDOS**) **ATTACK** LED TO THE DISRUPTION OF THE HEATING SYSTEMS FOR AT LEAST TWO HOUSING BLOCKS IN THE CITY OF **LAPPEENRANTA**, LITERALLY LEAVING THEIR RESIDENTS IN SUBZERO WEATHER



SECURITY CHALLENGES

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Panel on Networking and Systems - NexComm 2018

Theme: **Challenges in Urban and Mobility Systems and Networks**

Towards Graph Foundations for Addressing Urban Mobility Challenges

Leonard Petnga, Ph.D.

University of Alabama in Huntsville

Huntsville , AL USA

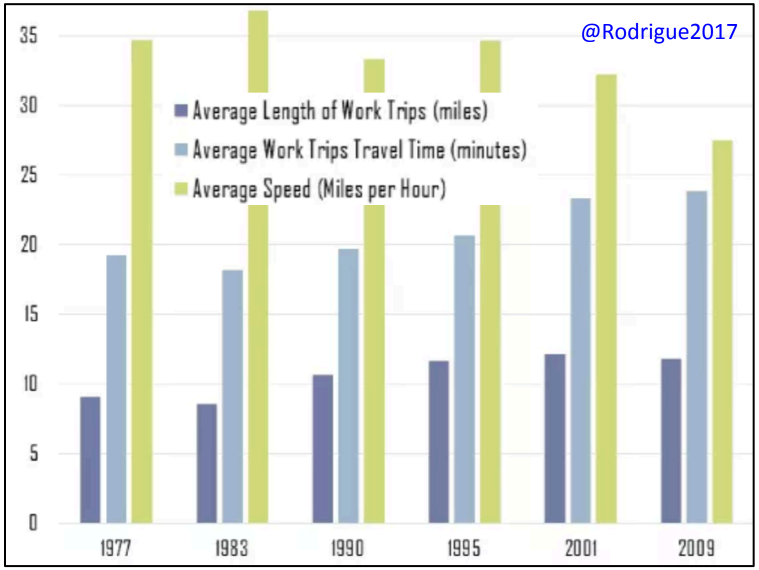
Athens, Greece

04/23/2018

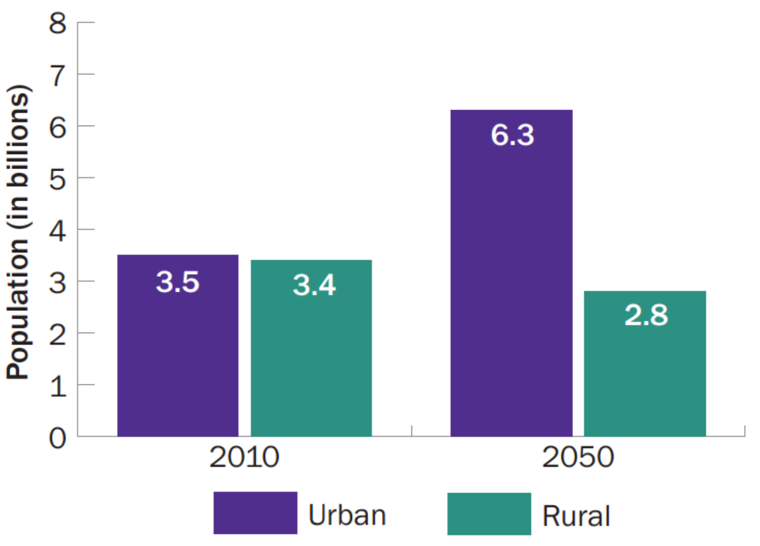
Mobility Challenges for Modern Cities

- **Persisting challenges:**
  - **Congestions** and **Parking** difficulties: Rapid development in individual => Extreme density of motor vehicles in urban areas
  - High **maintenance cost**, **environmental impact**, **energy** consumption, number of **accidents** and fatalities, **land** consumption (30-60% metro area)
- **Rising imbalances:**
  - ***Urban*** vs ***rural population*** distribution
  - ***Dwelling fossil fuel resources*** vs ***rising population*** ==> significant impact on multiple facets of mobility and location
  - ***Energy use and greenhouse gas emissions***: 20% human population responsible for 80% of energy consumption and emission

Home-to-Work Commute Profile, U.S.,1977-2009



Urban and rural population, 2010-2050



Urban Mobility in the 21st Century-Moss2012

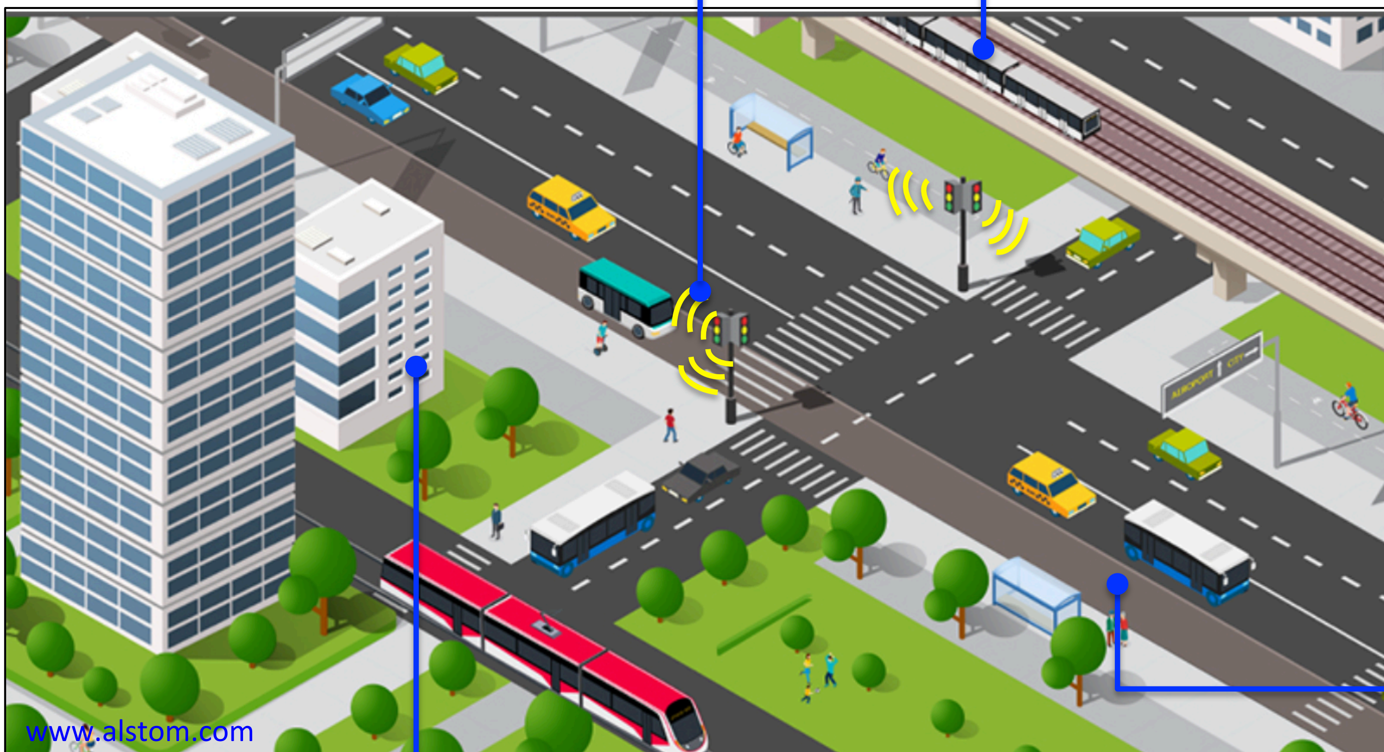
Piecewise & Limited "Smart" Technologies Solutions

TRAFFIC CONTROL/SMART ROADS

Monitoring of vehicles/ pedestrians levels for efficient traffic routing

ELECTRIC TRANSPORT

Electric vehicles and public transport with charging stations across the city



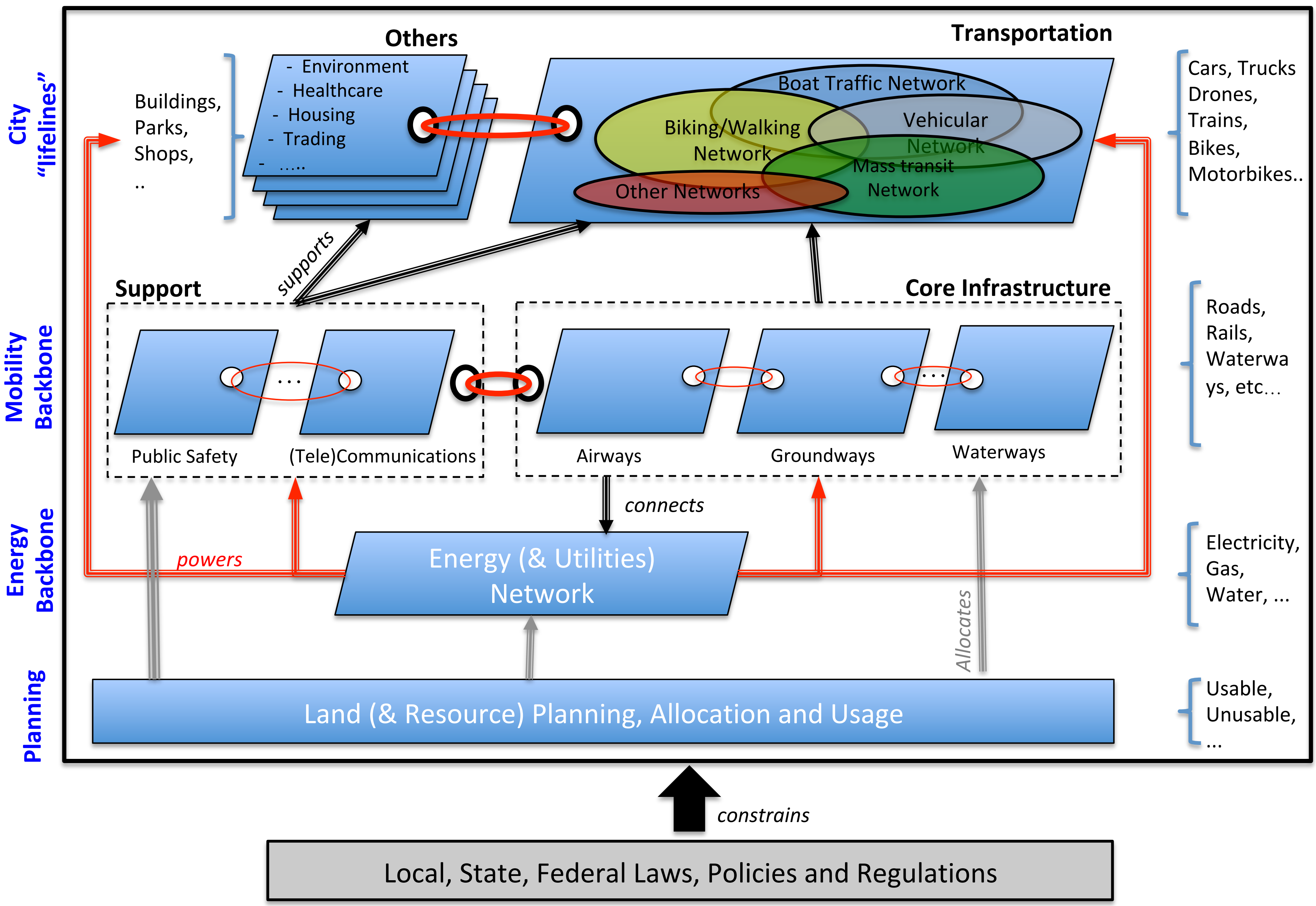
SMART PARKING

Dynamic, adaptive parking cost, occupancy and allocation

FAST LANES

Intelligent, adaptive fast and slow lanes

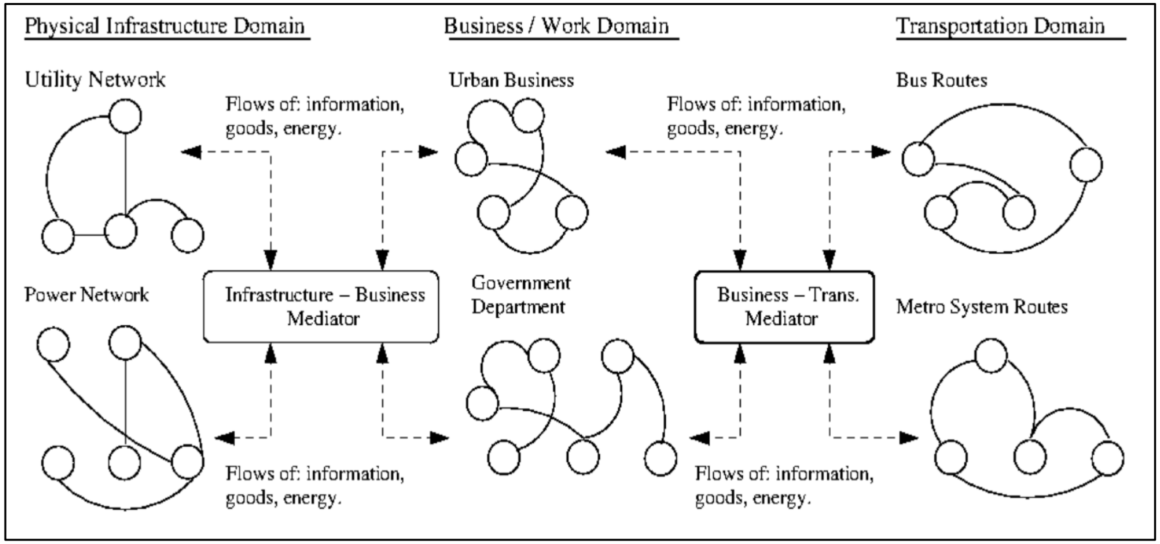
Urban Mobility Networks Hierarchy



Graph-based Foundations for Mobility

- **Current theoretical foundations**:
  - **Spatial interaction theories(Technical)**: Mobility = f(size & attraction origin and destination, 1/ travel time, 1/travel cost)
  - **Market-based theories (Economic)**: Mobility = f(Accessibility of location)
  - **Action space theory (Social)**: City = f(individual or collective appropriation of space over time)
- **Issues:** effects of laws, regulations? Technologies integration? Desired vs. undesirable evolution?
- **Exploring graph-based approaches**:
  - **Semantic graphs**: Formal, graph-based, Ontologies for multi-domain representations & reasoning
  - **Labeled graphs**: Relationship centric, cross-domain subgraph Pattern matching, Integration of Hierarchical, interconnected and heterogeneous data sources
  - **Urban mobility Applications** :
    - City resiliency: terrorist attack, natural disaster
    - City Planning and expansion

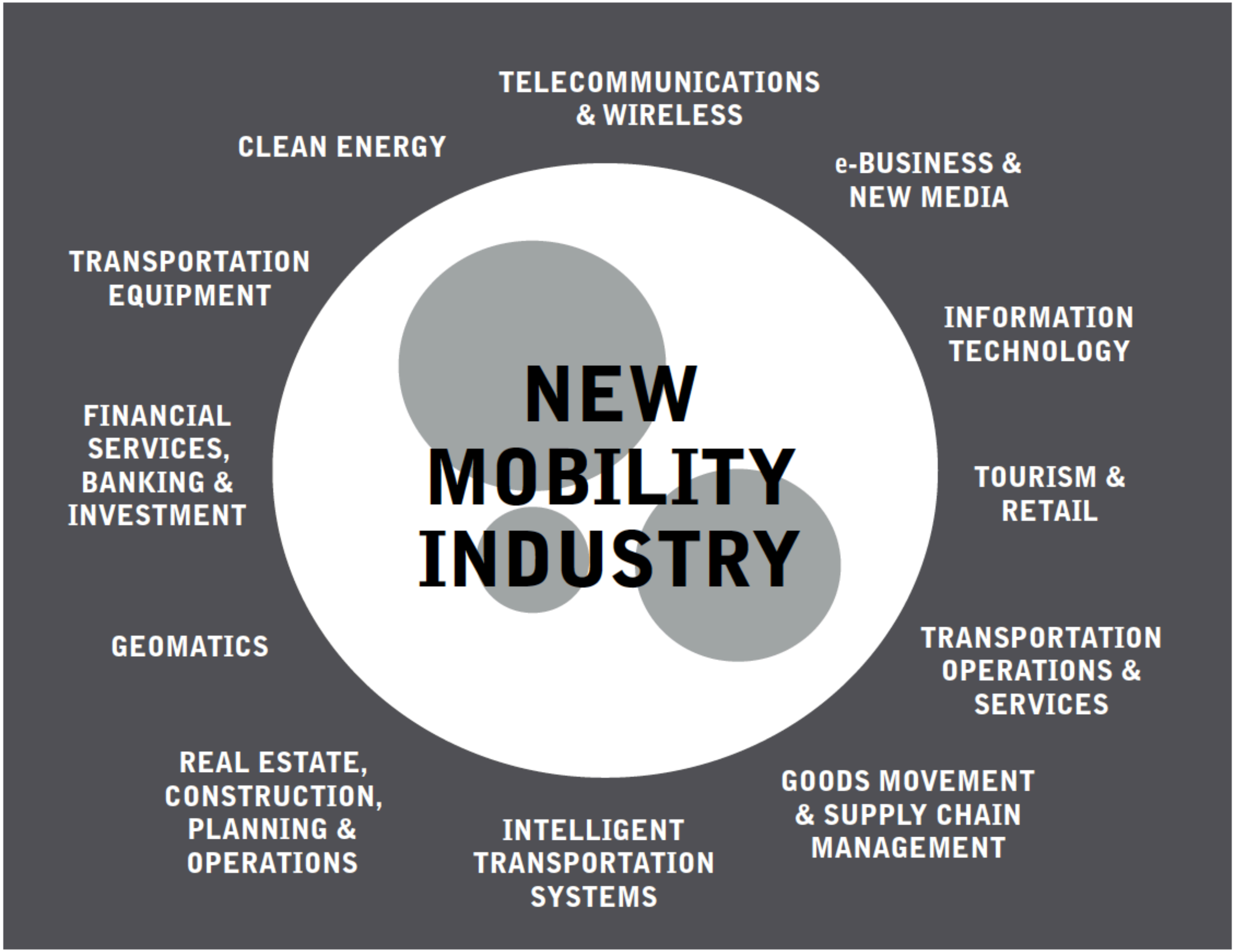
@Austin2015



THANKS!

DISCUSSION ?

Back up slide



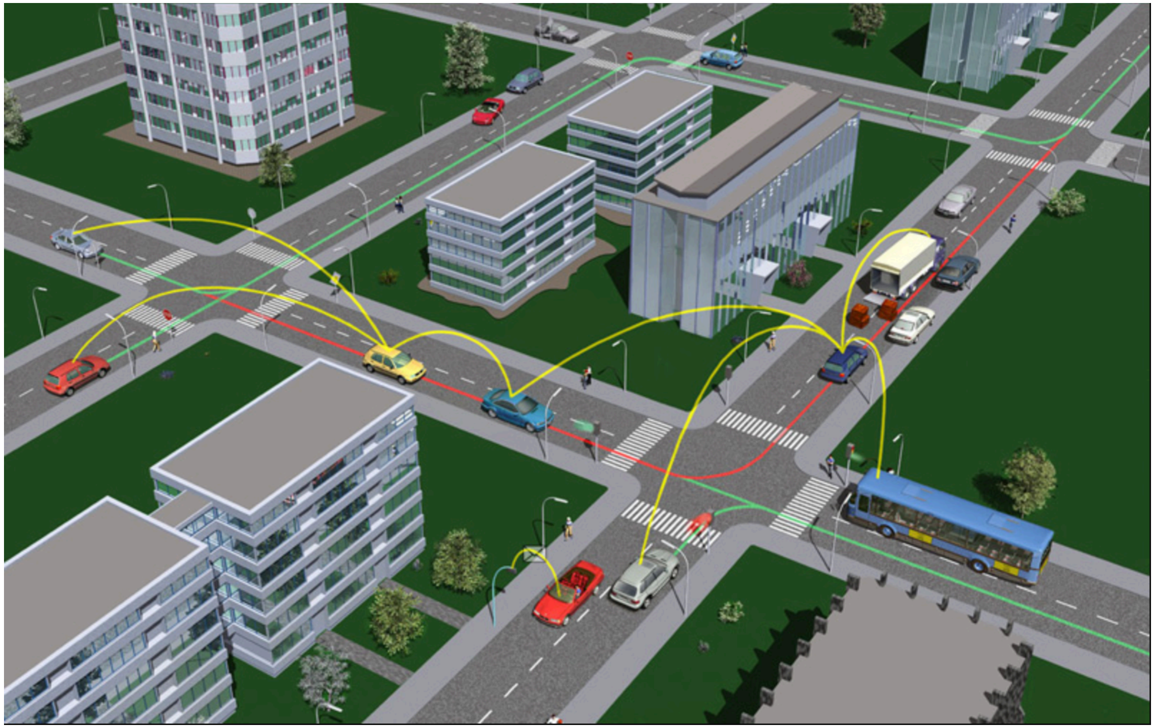
New Mobility Solutions for Urban Transportation-Zielinski20xx

V2V Background – Communication Protocols

1. JONATHAN M. GITLIN, *Vehicle-to-vehicle communication rule finally proposed by the government*, 12/14/2016, 5:59 PM, Avalaible at: https://arstechnica.com/cars/2016/12/car-talk-the-feds-publish-proposed-vehicle-to-vehicle-communication-rule/, Retrieved 04/18/18

2. Xue Yang, Feng Zhao, Jie Liu and Nitin H. Vaidya, *A Vehicle-to-Vehicle Communication Protocol for Cooperative Collision Warning*, available at: http://www.fengzhao.com/pubs/yang_x_v2v.pdf, Retrieved 04/18/18

3. Milt Baker and Lawrence Hill, *An Alternative Safety Communications Protocol for V2V and V2I*, Automotive Communications Systems , Hill Automotive Communications Systems | Jul 01, 2008. Available at: http://www.electronicdesign.com/automotive/alternative-safety-communications-protocol-v2v-and-v2i



4. Bill Howard, *V2V: What are vehicle-to-vehicle communications and how do they work?*, Extreme Tech; 02/06/2014, Available at: https://www.extremetech.com/extreme/176093-v2v-what-are-vehicle-to-vehicle-communications-and-how-does-it-work

Expected AVs share on roads (estimated)

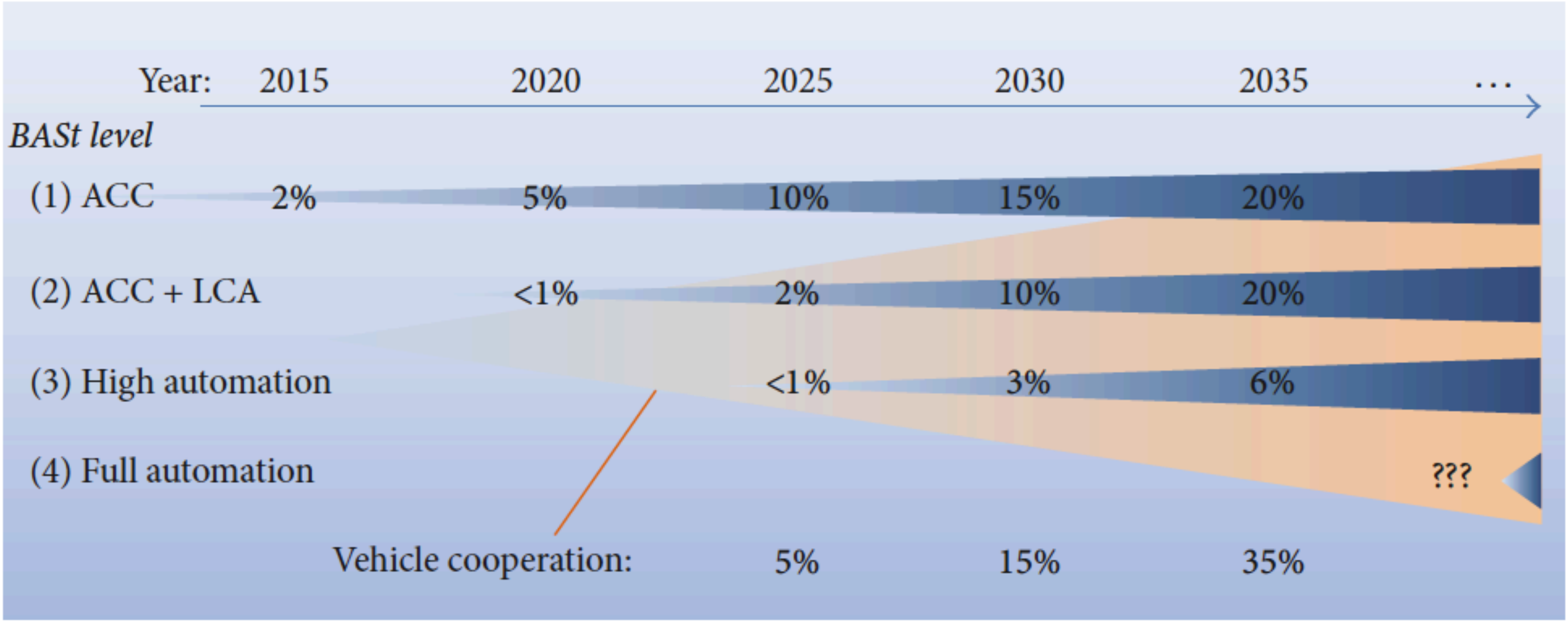


FIGURE 1: Estimated automated vehicle share on roads.

Legend:

ACC: Adaptive Cruise Control;

LCA: Lane Change Assistance

Source: S. C. Calvert, W. J. Schakel, and J. W. C. van Lint, *Will Automated Vehicles Negatively Impact Traffic Flow?*, Journal of Advanced Transportation, Volume 2017, Article ID 3082781, 17 pages

NexComm 2018

Panel on Networking and Systems

Theme: Challenges in Urban and Mobility Systems and Networks

Networking technologies for V2X communications

Eugen Borcoci
University Politehnica Bucharest
Electronics, Telecommunications and Information Technology Faculty (ETTI)

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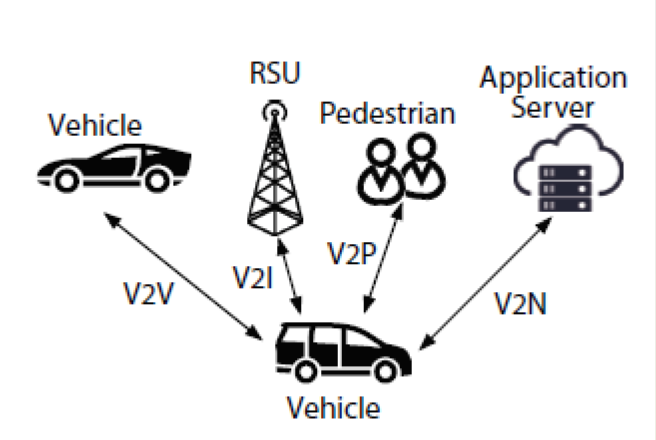
NexComm 2018, Athens 22-26 April 2018

Networking technologies for V2X

- **Vehicular Networks** *(Ref. [1][2][3])*
- **Early development: > 1990**
- **New developments in the context of IoT**
- **Communication types: V2V, V2I, V2P, V2N**
- **General: V2X**



- **Applications and use cases**
  - *Active road safety applications*
    - Warning: Intersection collision, Overtaking vehicle, Head/Rear-end collision risk, Emergency vehicle, Pre-crash, Stationary vehicle, Traffic condition, Signal violation, Control loss..
    - Assistance: Lane change, Co-operative merging
    - Emergency electronic brake lights
  - *Traffic efficiency and management applications*
    - Speed management, Co-operative navigation
  - *Infotainment applications*
    - Co-operative local services, Global Internet services

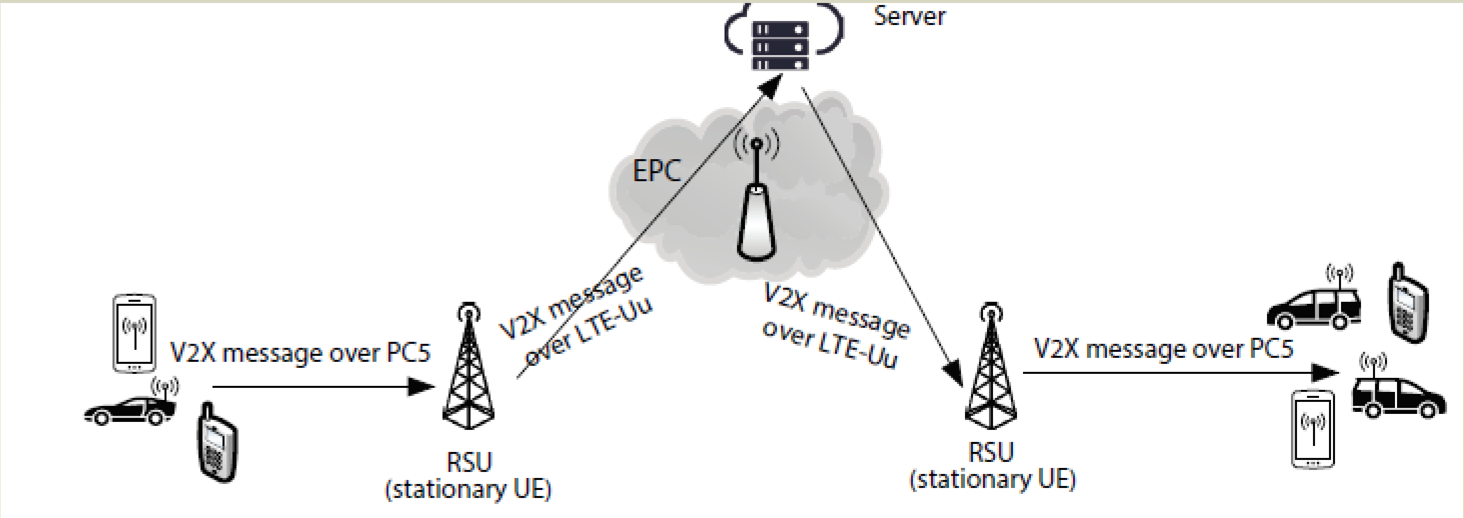
Networking technologies for V2X

- **V2X – recent trends** *(Ref. [1][2][3])*
  - **Driving factors**
    - Autonomous driving
    - Increase in number of vehicles – and associated traffic events
    - Industrial needs
    - Smart cities needs
  - V2X : standardized in the IEEE 802.11p and 3GPP, and further discussed in 5G automotive association (AA)
  - **Vehicular Networks (VANET) → Internet of Vehicles (IoV)**
  - IoV can be considered as a part of IoT "umbrella"
  - Cooperation with other IoT applications

  - **Novel support technologies**
    - Rich set of sensors and smart devices
    - Cloud computing/ Edge/Fog computing (e.g. ETSI MEC)
    - 5G – Heterogeneous networks, 5G slices dedicated to V2X
    - Flexible management and control based on
      - Network function Virtualization (NFV)
      - Software Defined Networking (SDN)
    - Information Centric Networking (ICN/CCN)

Networking technologies for V2X

- **C-V2X example**
  - Cellular V2X (C-V2X) - developed within the 3rd Generation Partnership Project (3GPP)
  - to operate in both V2V and V2N modes
  - It can achieve the V2X requirements in the most efficient manner the way to connected and automated driving
  - C-V2X offers superior performance over traditional IEEE 802.11p



Source [4]: X.Wang et. al., "An Overview of 3GPP Cellular Vehicle-to-Everything Standards", https://www.researchgate.net/publication/321088744

Networking technologies for V2X

- **C-V2X**

- V2V communications are based on D2D communications
- defined as part of ProSe services in Release 12 and Release 13 of the specification

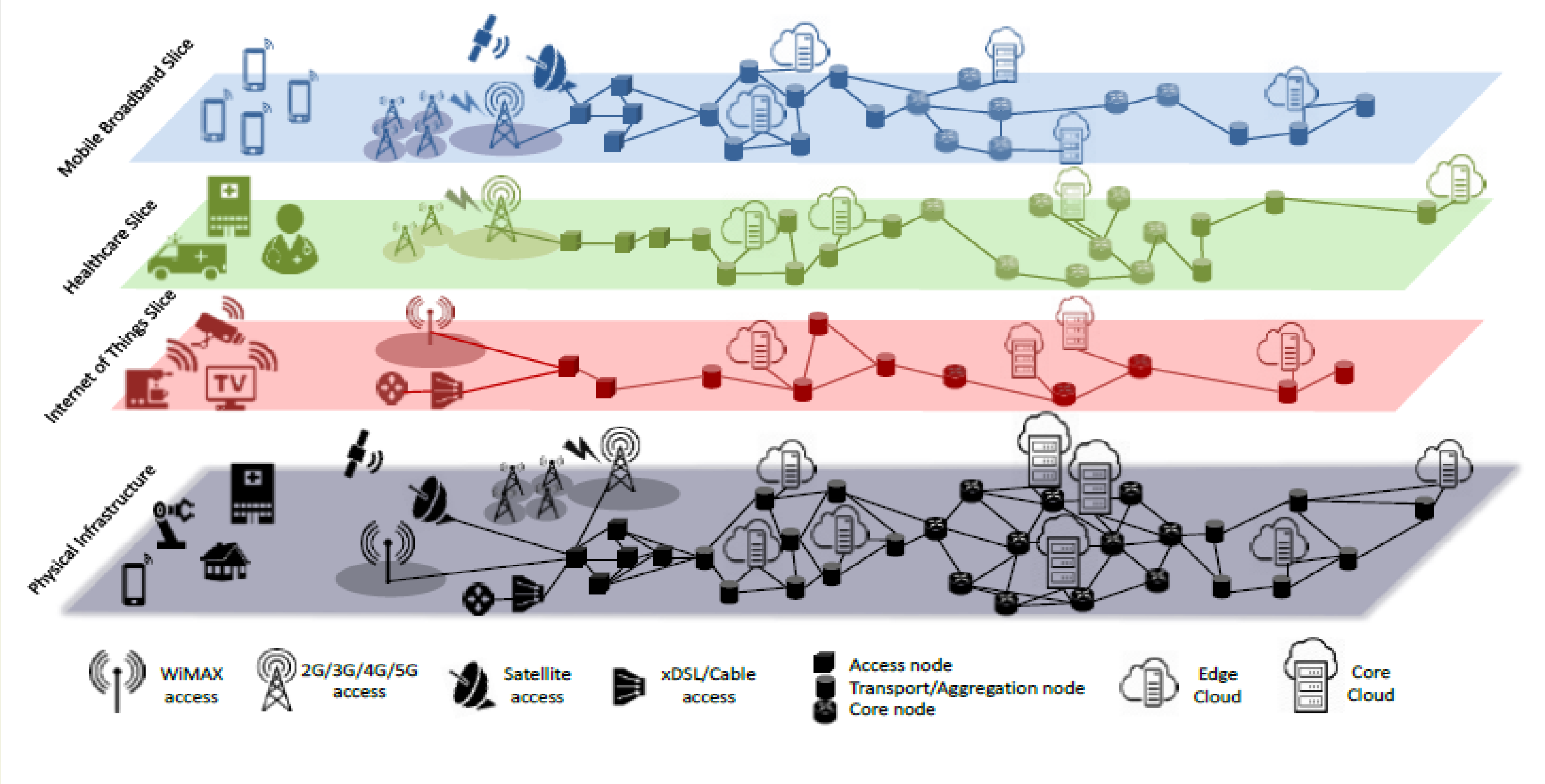
- As part of ProSe services, a new D2D interface (designated as PC5, also known as sidelink at the physical layer) was introduced

- and now as part of the V2V WI it has been enhanced for vehicular use cases, specifically addressing high speed (up to 250Kph) and high density (thousands of nodes)

Source [4]: X.Wang et. al., "An Overview of 3GPP Cellular Vehicle-to-Everything Standards", https://www.researchgate.net/publication/321088744

Networking technologies for V2X

- **5G slicing example-** some slice can be dedicated to V2X



Source [5]: J. Ordonez-Lucena, et.al., "Network Slicing for 5G with SDN/NFV: Concepts, Architectures and Challenges" , IEEE Communications Magazine, 2017, Citation information: DOI 10.1109/MCOM.2017.1600935

Networking technologies for V2X

- **Conclusions**
  - V2X –emergent technology
  - IoV – significant evolution (architecture, implementations, ..)
  - Still – many challenges and open research issues
    - SDN, NFV management and control
    - Edge/fog computing to serve V2X/IoV
    - Security
    - V2X in network sliced environment

- Thank you !

Networking technologies for V2X

- **References**

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Networking technologies for V2X

- **Acronym list**
  - ARIB Association of Radio Industries and Businesses
  - CALM Continuous Air-interface Long and Medium range
  - DSRC Dedicated Short-Range Communications)
  - D2D Device to Device
  - EPC Evolved Packet Core
  - LTE Long-Term Evolution
  - LTE-A Long-Term Evolution Advanced
  - M2M Machine-to-Machine
  - NFC Near Field Communication
  - OBU On Board Unit
  - RSU Road Side Unit
  - NFV Network Function Virtualisation
  - SDN Software Defined Networking
  - V2V Vehicle to Vehicle
  - V2I Vehicle to Infrastructure
  - V2X Vehicle to anything
  - V2P Vehicle to Pedestrian
  - V2N Vehicle to Network
  - VCC Vehicular Cloud Computing
  - WAVE Wireless Access in Vehicular Environments
  - WSNs Wireless Sensor Networks

Networking technologies for V2X

- **Vehicular Networks**
- **Rich set of requirement**
  - a) Strategic
  - b) Economical
  - c) Legal
  - d) Standardization
  - e) System (technical) capabilities requirements
    - Functional: security, privacy, reliability, connectivity (V2V, V2I, V2X), positioning, mode (unicast, geocast, broadcast)
    - Performances: bandwidth, delay, QoS, (depending on classes of applications)
- Challenges (still questions and concerns):
  - reliable and scalable low latency connectivity
  - secure and reliable systems
  - applications for improved safety and cooperative driving
- **Organizations and Standards**
  - ITS, IEEE , ITU, ISO, ARIB, ETSI, …
  - IEEE 802.11p, WAVE, IEEE 1609.x, ISO CALM, …
- **Access technologies**
  - Bluetooth, ZigBee, WiFI/DSRC, WiMAX, 3G/4G- LTE, 5G, ….

Networking technologies for V2X

- **Backup slides**
  - **Vehicular Networks**
    - **Example: WAVE stack**