Wireless Information-Centric Networking with Edge Computing for Vehicular Applications

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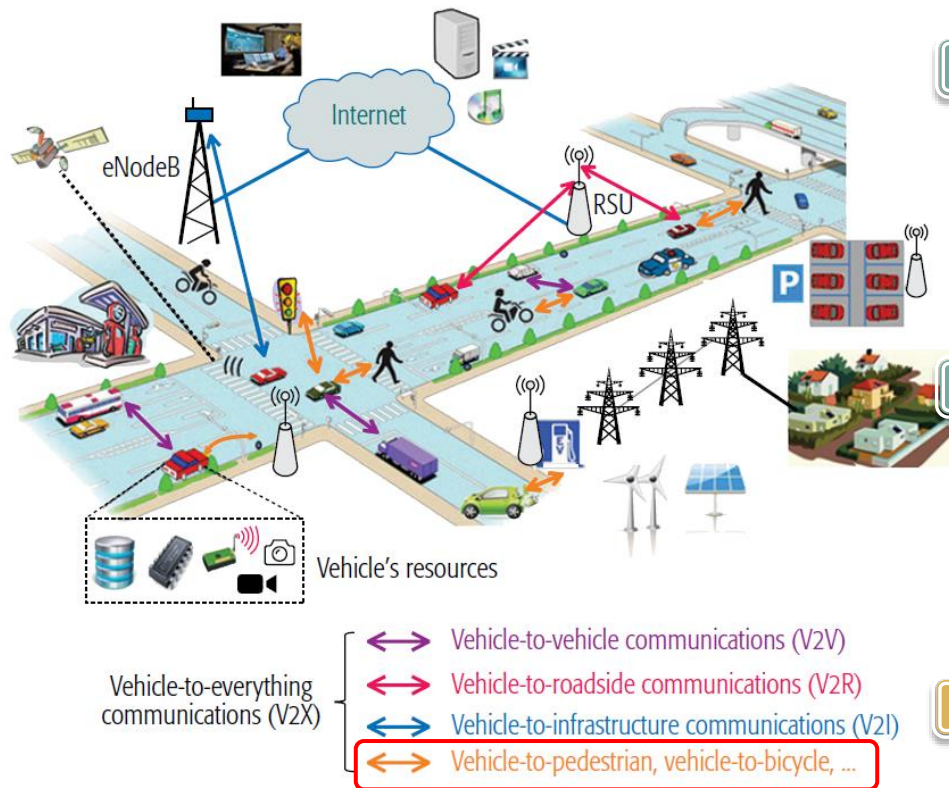*BcNLab at Hongik University*

Outline

- V2X Networks

- ICN/NDN/CCN

- MEC/Fog/Cloudlet Computing

- ICN + Edge Computing

- Issues on ICN for Multi-Hop V2X

- Conclusion

Vehicular Networks

VANET, Connected Vehicles, V2X, C-ITS, VAN

Vehicle-to-everything communications (V2X)

- ↔ Vehicle-to-vehicle communications (V2V)
- ↔ Vehicle-to-roadside communications (V2R)
- ↔ Vehicle-to-infrastructure communications (V2I)
- ↔ Vehicle-to-pedestrian, vehicle-to-bicycle, ...

Information-Centric Networking for Connected Vehicles: A Survey and Future Perspectives, IEEE Commun. Mag. Feb. 2016

Current & Future

Generating & Gathering
Transmitting & Receiving
Massive Data

Requirements

Delay Tolerant or Real Time Comms.
Distributed & Connectionless Comms.
Information Analysis
Large Computing Capability

Reality

IP & Connection-Oriented
Centralized & CC-dependent Architecture
High Traffic Loads
Long Latency

Solutions

Information Centric Networking
+
Edge Computing

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Key idea of ICN (1)

❑ In a word ➔ Connectionless & Asynchronous Communications

❑   Different from TCP/IP-based networking in terms of

  ❑ **Naming**

  ❑ **Caching**

  ❑ **Content Security**

  ❑ **Content Forwarding & Routing**
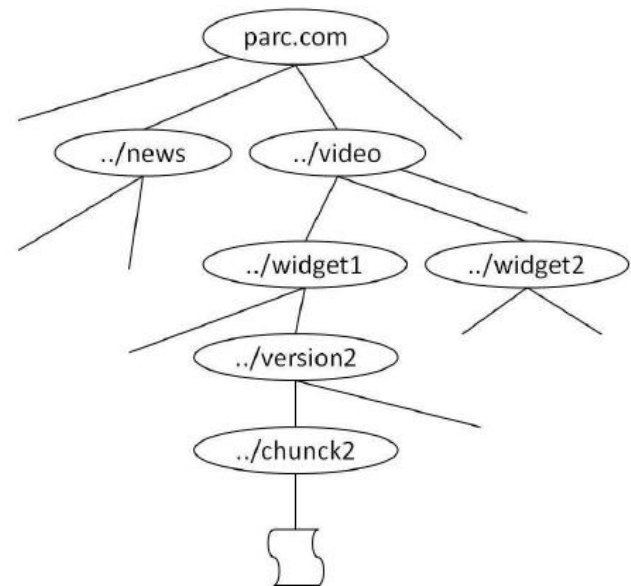
Key idea of ICN (2)

❑ To search for content Using "Name", no IP address !

- ❑ Focuses on content rather than IP addresses ("Where" is replaced by "What")

- ❑ Data is directly requested at the network level (not its holder, no more DNS : less delay)

- ❑ Packets are routed and forwarded based on names.

- ❑ Solution for the lack of IP addresses and IoT/M2M

- ❑ How to construct and design "Name"?

Example of hierarchical naming:
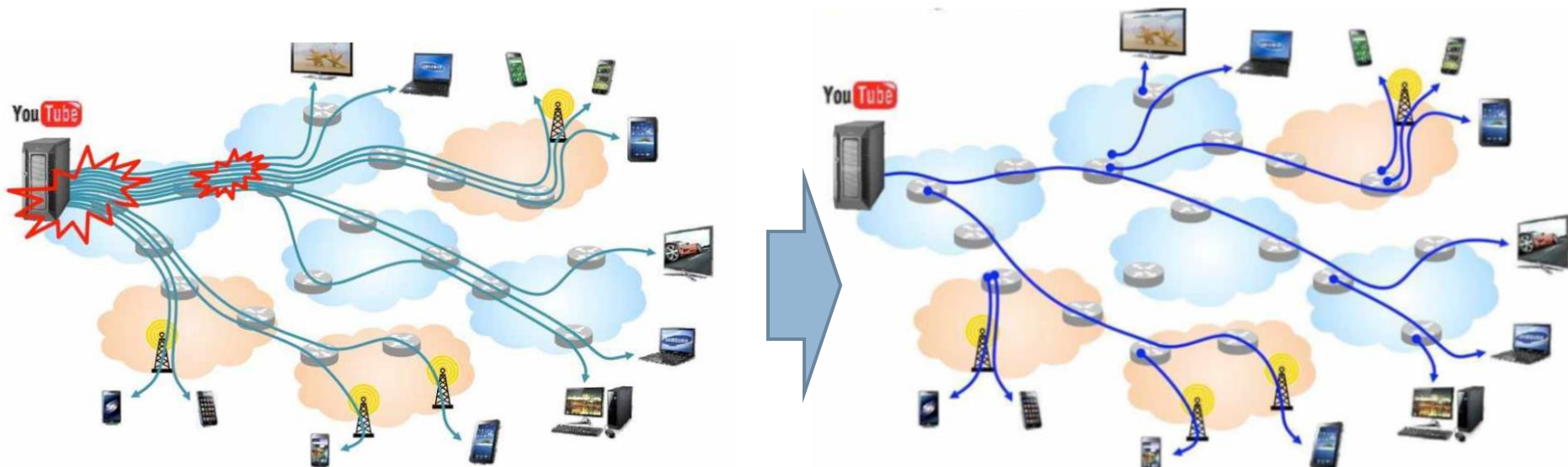*ccnx:/parc.org/video/widget1/version2/chunk2*

Key idea of ICN (3)

❑ To cache contents in any node !

- ❑ Rely on close data storage (*on-path caching*)
- ❑ Anybody with the content can be a content server!
- ❑ Reduce content retrieval time
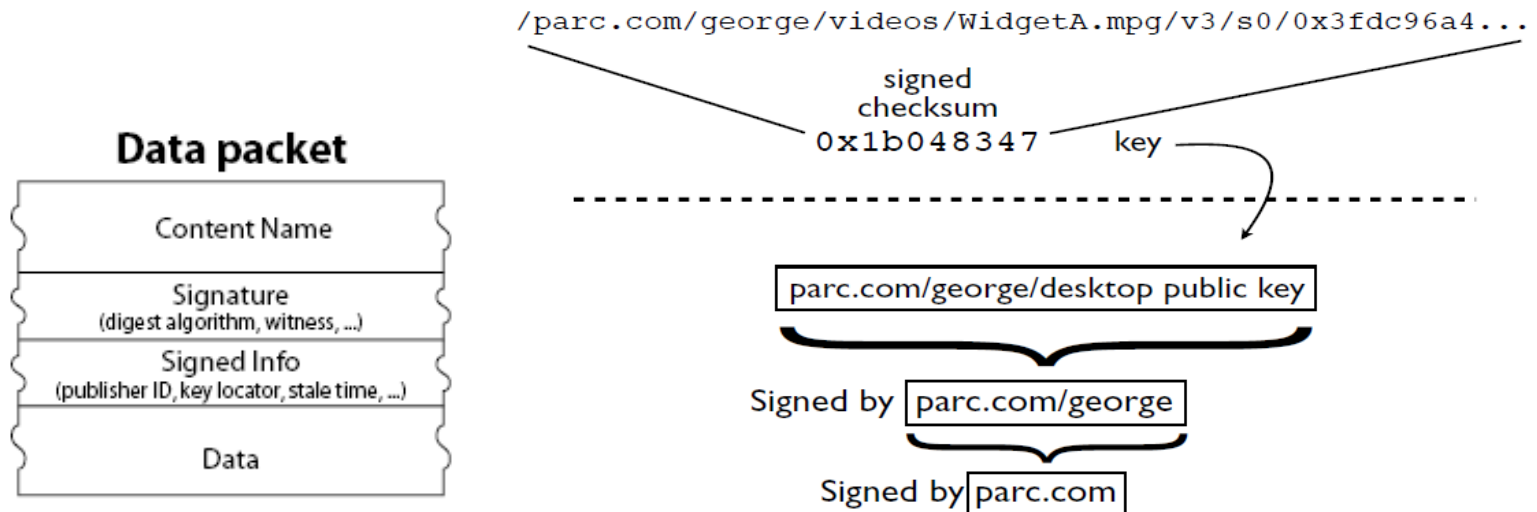- ❑ Cooperate with Delay-Tolerant-Network (DTN)

Key idea of ICN (4)
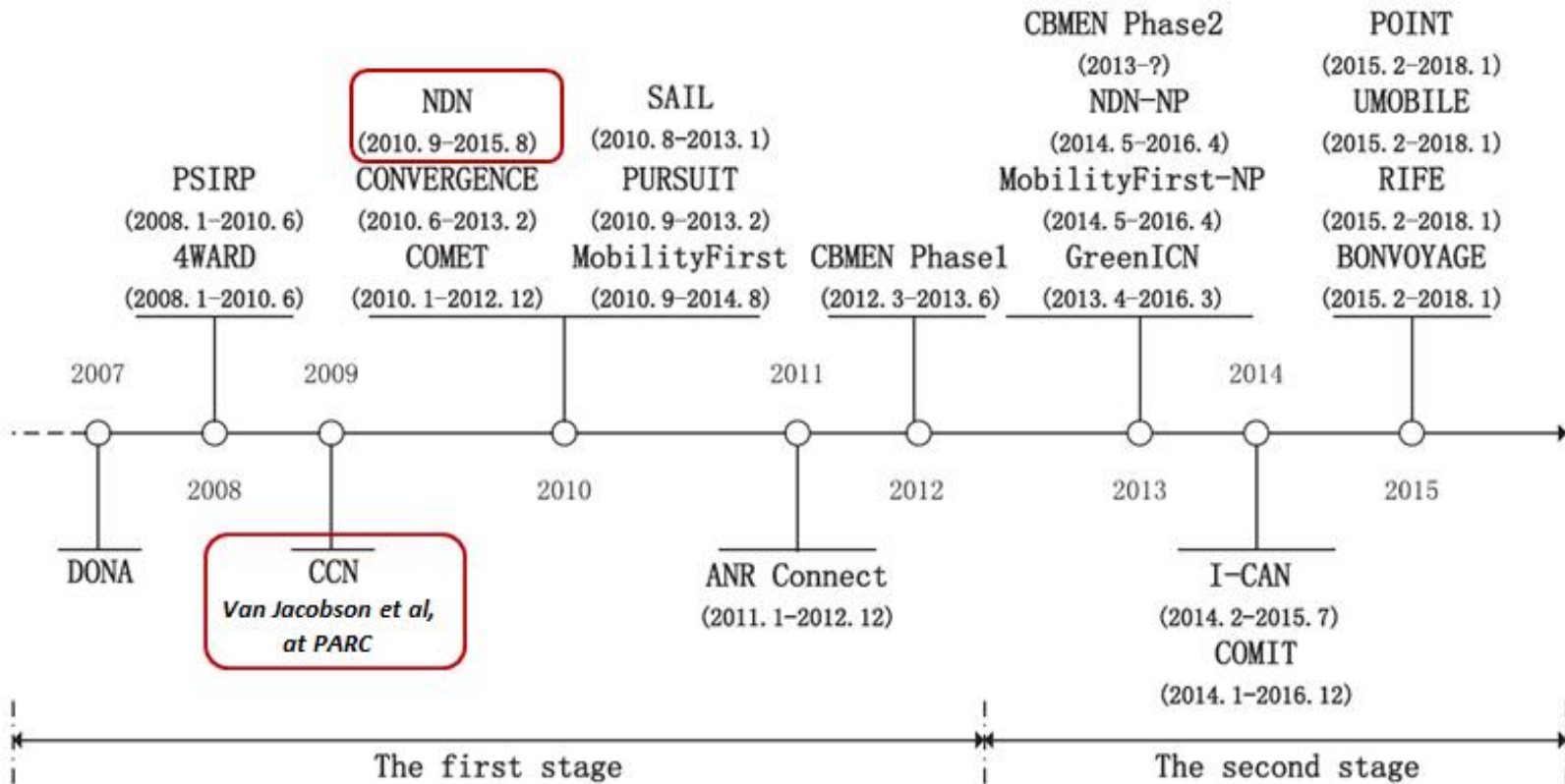
❑ To secure 'Content' itself, not endpoints

- ❑ Regardless of where packets travel across the network, content is protected from damage, alteration, or snooping from unauthorized parties.
- ❑ Name-content mapping verification via per-data packet signature
    - ❑ Data packet is authenticated with digital signature

CCN trust establishment by associating content namespaces w/ public keys
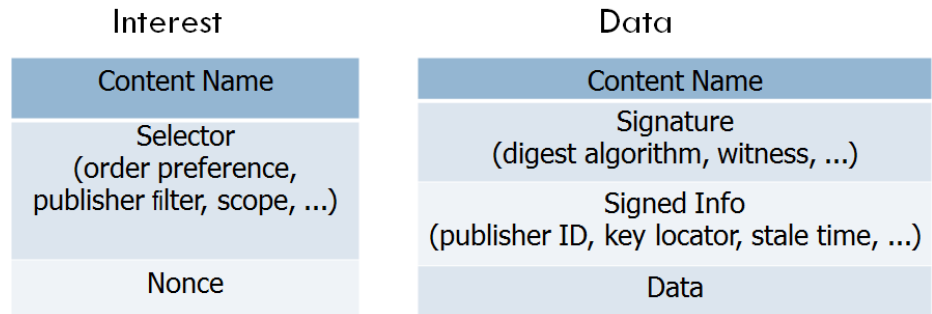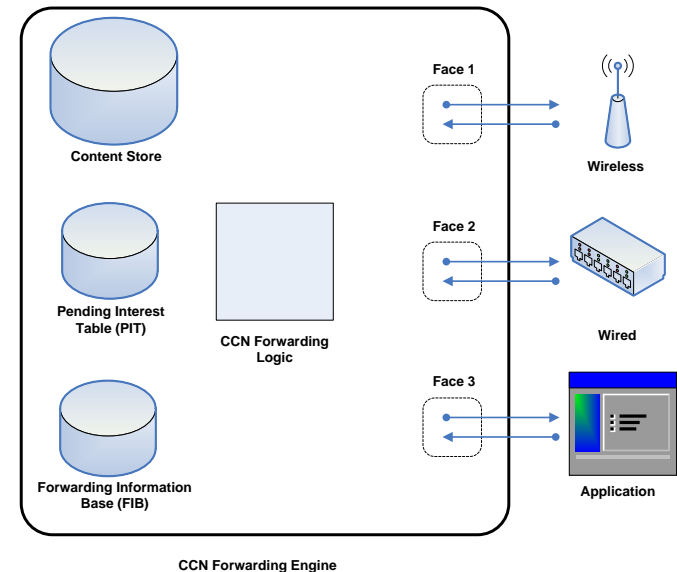
Key idea of ICN (5)

Key idea of ICN (6)

- ## Message Types
  - Interest
  - Data

Interest

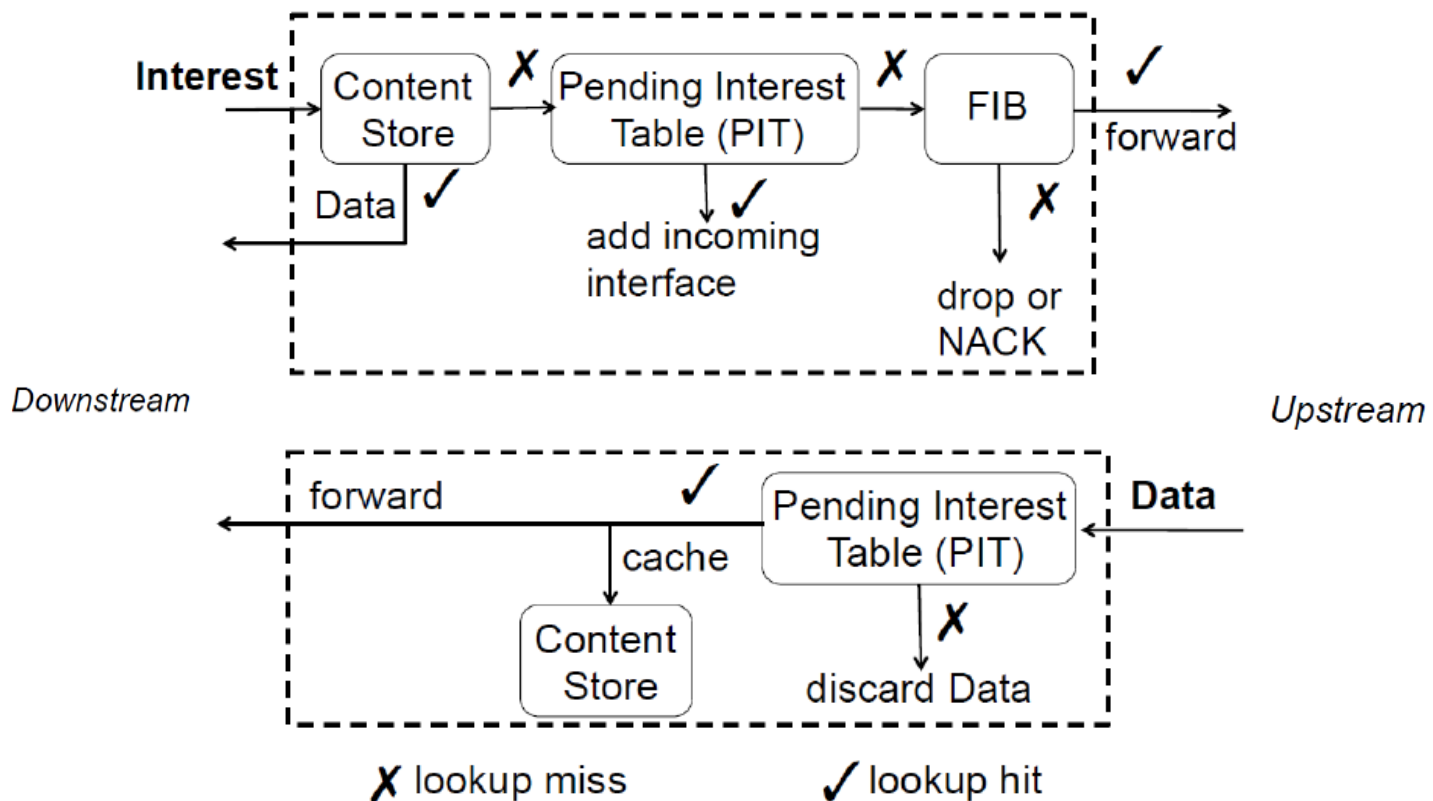| Content Name |
| Selector (order preference, publisher filter, scope, ...) |
| Nonce |

Data

| Content Name |
| Signature (digest algorithm, witness, ...) |
| Signed Info (publisher ID, key locator, stale time, ...) |
| Data |

- ## Data Structures
  - Content Store (CS)
  - Pending Interest Table (PIT)
  - Forwarding Information Base (FIB)
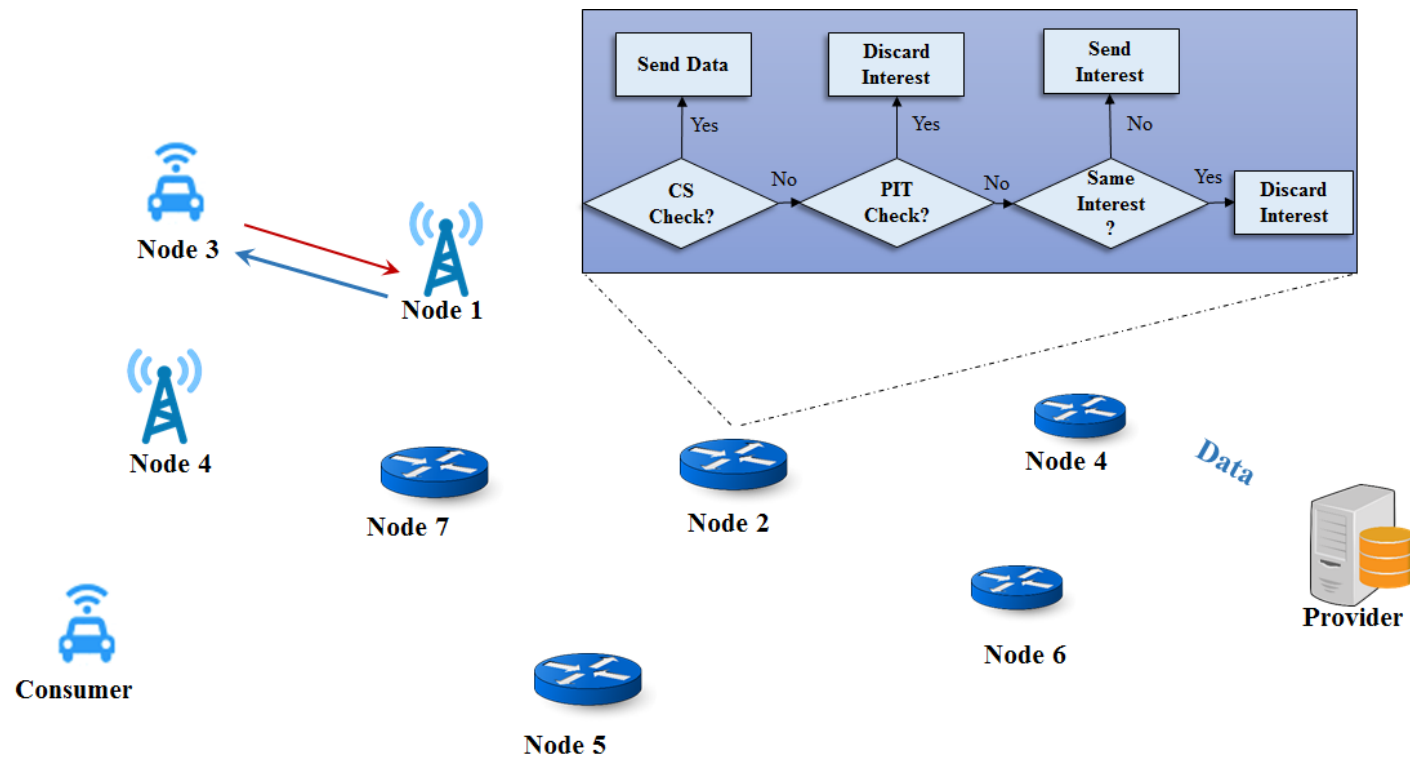

CCN Forwarding Engine

Key idea of ICN (7)

❑ Forwarding / Routing

❖ Source needs to announce its contents cross over the network in advance.

Key idea of ICN ()

ICN for Connected Vehicle

□ Why ICN for Vehicular Networks ?

  ▫ More than 15years researches, but there is no VANET implementations
    "No Perfect Routing protocol for VANETs"

  ▫ Mobility support: enable two communicating parties to interact asynchronously and seamlessly without establishing and maintaining an end-to-end connection

  ▫ Intrinsic Security: Not over the transport channel, but Data itself

  ▫ Location-independent naming: Eliminate the need of reassigning the host identifier(such as IP address) to the moving node.

  ▫ In-network caching: to exploit broadcast nature of wireless channel to listen and subsequently cache content ➔ lower redundant requests and content retrieval latency.

  ▫ Broadcast nature: Might be better reliability

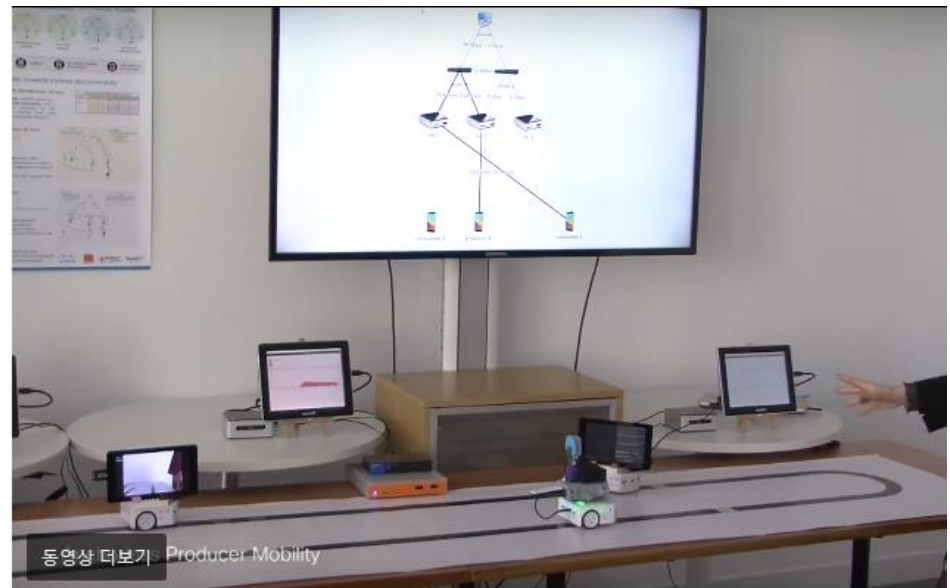*BcNLab at Hongik University*

ICN with Connected Vehicle

- Demonstration of ICN with connected car by Cisco
  - Community ICN (CICN): CISCO's open-source project
  - Features
    - Seamless Mobility,
    - Asynchronous Multicast,
    - Native Multihoming
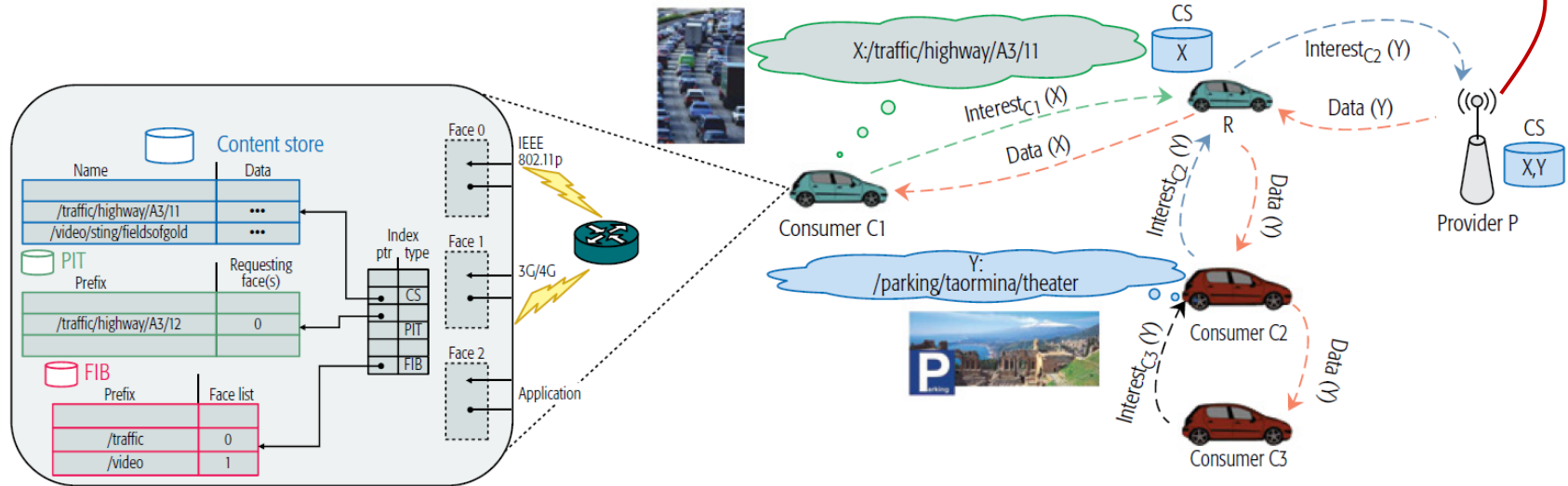   - Anchorless Producer Mobility

http://news.itu.int/key-to-5g-networks-leveraging-information-centric-networking-icn/

ICN with Connected Vehicle

Where to analysis Information ?
*Where to store huge data?*

Information-Centric Networking for Connected Vehicles: A Survey and Future Perspectives, IEEE Commun. Mag. Feb. 2016

Edge Computing

- Key Idea of Edge Computing

  ✓ Let's place mini-Cloud-like functions close to users

  ✓ Let's place Cloud-like service around users

  ✓ Let's make heterogeneous mini-Cloud servers cooperative

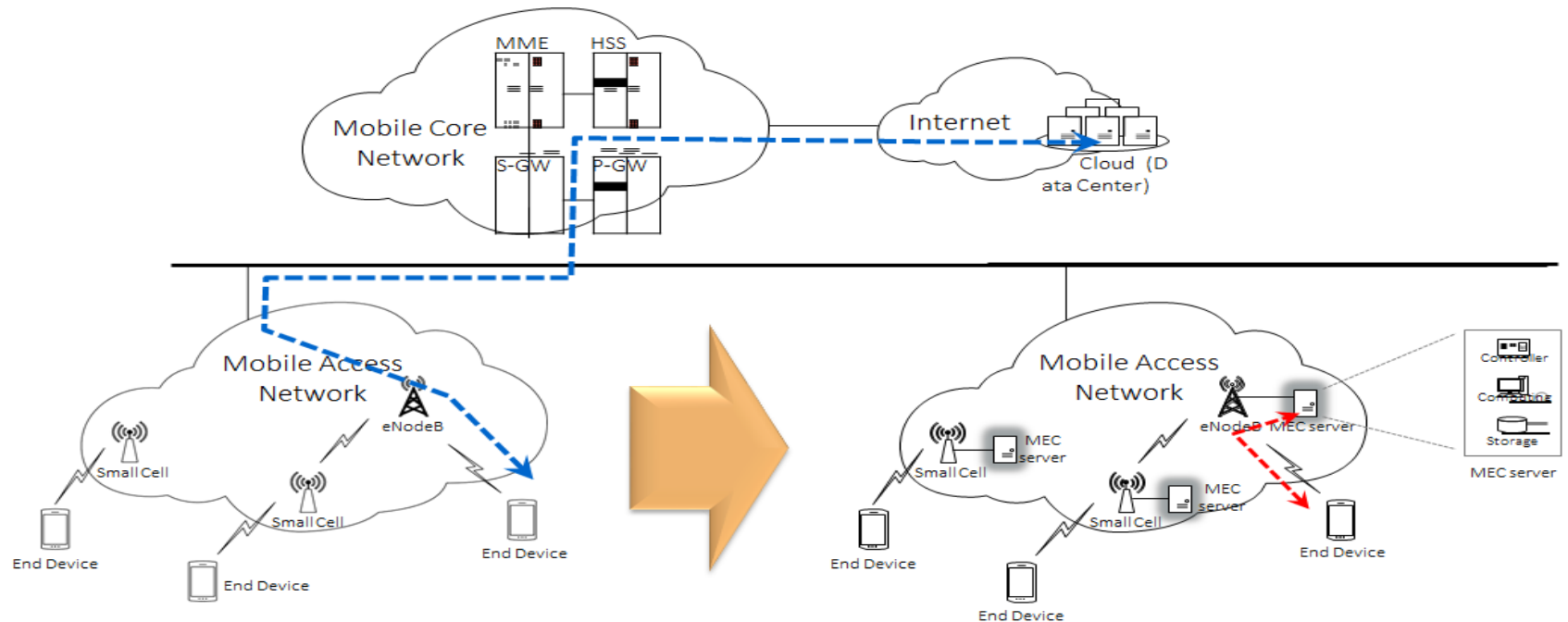 ✓ Only if necessary, let's forward the service to Cloud Data Center

"Edge (Cloud) Computing"

MEC, Fog, Cloudlet, Mist, m-DC
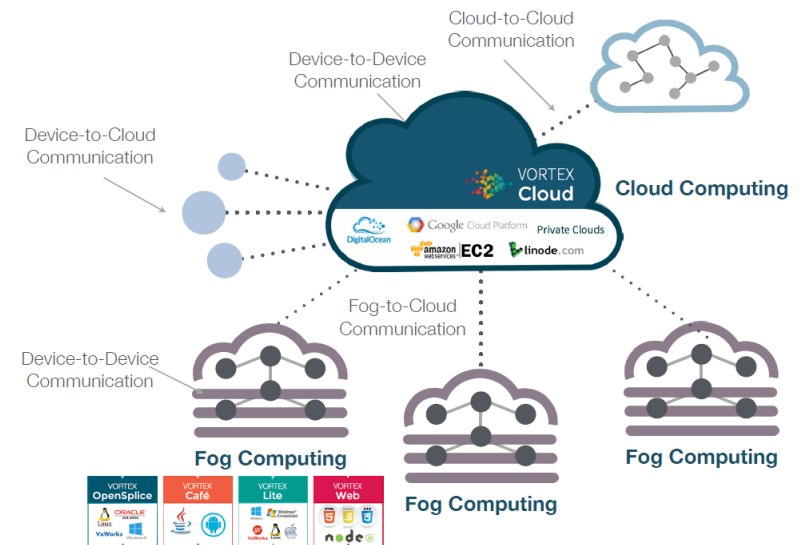
Source: "Fog Computing with Vortex" PrismTech

Cloud Computing vs. Edge Computing

Cloud Computing	Edge Computing
Large Storage, High Computing performance	Less Storage, Less Computing Performances
Centralized	Distributed
Far from the user	Close to the user
Long Delay	Less Delay

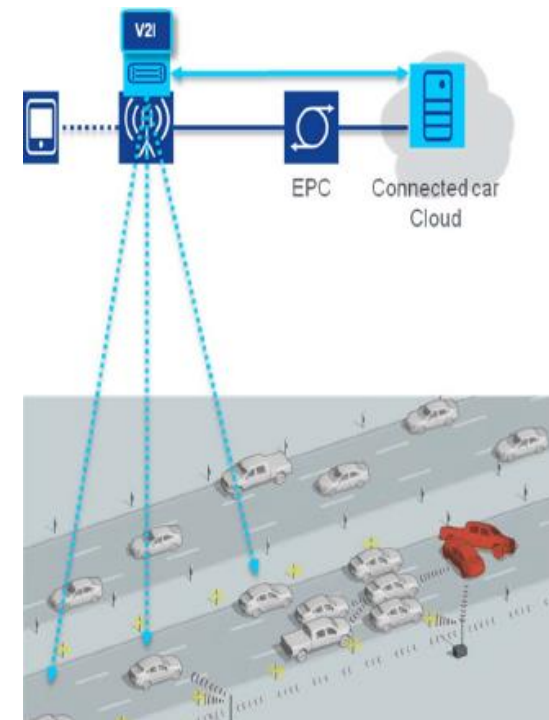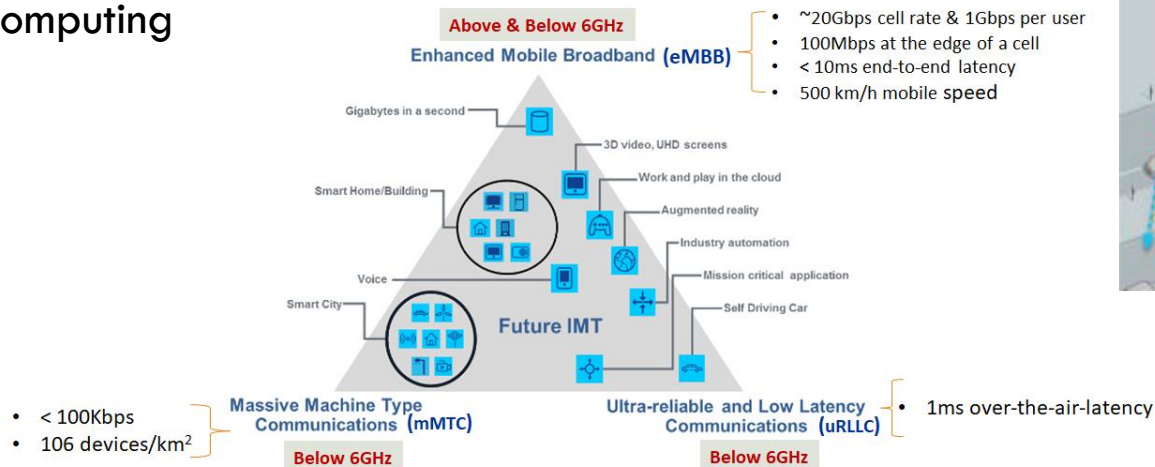Source: http://www.collaberatact.com/cloud-different-edge-iot-environment/

Candidates for Edge Computing - MEC

● **Mobile Edge Computing (MEC)**

- Multiple-access Edge Computing

- Lead by ETSI from 2014.

- MEC pushes the CC capabilities close to the Radio Access Networks (RAN) in Cellular-based networks

- ETSI is developing a system architecture and std. for a number of APIs

- The most active organizations among candidates for edge computing

ETSI GS MEC-IEG 004 V1.1.1 (2015-11)

Above & Below 6GHz
Enhanced Mobile Broadband (eMBB)
- ~20Gbps cell rate & 1Gbps per user
- 100Mbps at the edge of a cell
- < 10ms end-to-end latency
- 500 km/h mobile speed

Gigabytes in a second

3D video, UHD screens
Work and play in the cloud
Smart Home/Building
Augmented reality
Industry automation
Voice
Mission critical application
Smart City
Self Driving Car

Future IMT

- < 100Kbps
- 106 devices/km²

Massive Machine Type Communications (mMTC)
Below 6GHz

Ultra-reliable and Low Latency Communications (uRLLC)
Below 6GHz
- 1ms over-the-air-latency

● **Fog Computing (FC)**

- Proposed by Cisco (2011) and managed Open Fog Consortium (OpenFog)

- Extends the CC to the edge of networks, in particular wireless networks for the Internet of Things

- A <u>highly virtualized platform</u> that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers.

- <u>Fog node can be any device with computing, storage, and network connectivity</u>

- Focusing on <u>time-sensitive and data-intensive IoT application & service</u>

- The Fog is about pooling data and resources.

https://www.rtinsights.com/fog-vs-cloud-computing-architectures/

https://www.rtinsights.com/what-is-fog-computing-open-consortium/
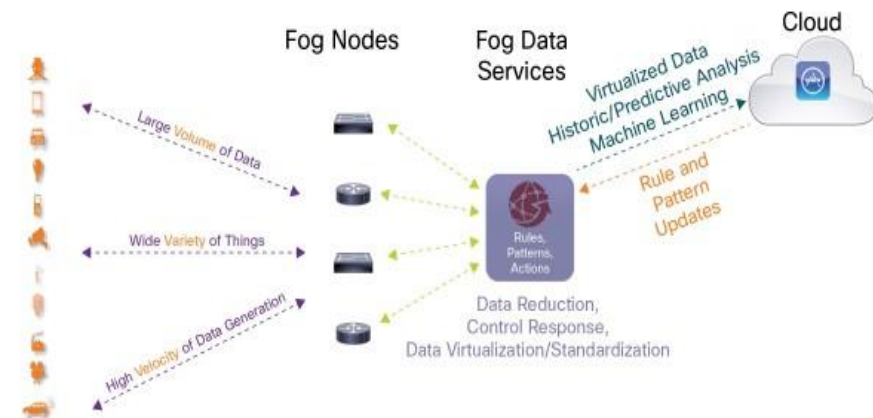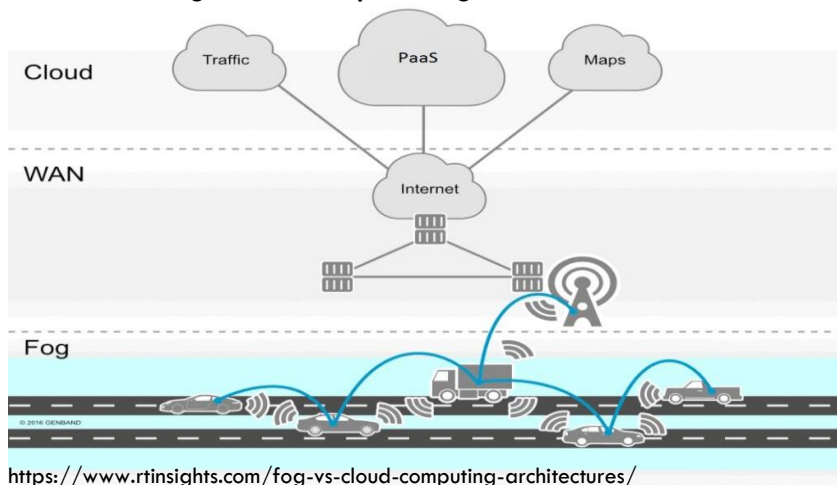
Candidates for Edge Computing-Cloudlet

● **Cloudlet**

- Concept was proposed (2009) and a prototype implementation is developed by Carnegie Mellon Univ. (2013)

- Expand to Open Edge Computing (OEC)

- Cloudlets are decentralized and widely-dispersed Internet infrastructure

- Elijah-Cloudlet project: OpenStack++ (a set of cloudlet-specific API as OpenStack extensions)

Elijah   **Cloudlet-based Mobile Computing**

Gabriel   **Wearable Cognitive Assistance using cloudlets**

Publications People Development Press

A *cloudlet* is a new architectural element that arises from the convergence of mobile computing and cloud computing. It represents the middle tier of a 3-tier hierarchy: mobile device --- cloudlet --- cloud. A cloudlet can be viewed as a "data center in a box" whose goal is to "bring the cloud closer". A cloudlet has four key attributes:

- **only soft state:** It is does not have any hard state, but may contain cached state from the cloud. It may also buffer data originating from a mobile device (such as video or photographs) en route to safety in the cloud. The avoidance of hard state means that each cloudlet adds close to zero management burden after installation: it is entirely self-managing.
- **powerful, well-connected and safe:** It possesses sufficient compute power (i.e., CPU, RAM, etc.) to offload resource-intensive computations from one or more mobile devices. It has excellent connectivity to the cloud (typically a wired Internet connection) and is not limited by finite battery life (i.e., it is plugged into a power outlet). Its integrity as a computing platform is assumed; in a production-quality implementation this will have to be enforced through some combination of tamper-resistance

What is edge computing?

Edge computing is a new network functionality that offers connected compute and storage resources right next to you! Wherever you are!
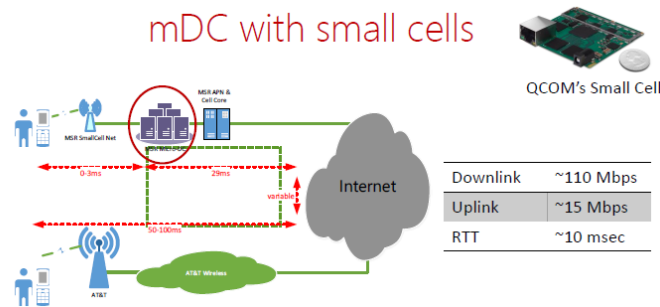
Candidates for Edge Computing

- The others
  - Mist
  - m-DC
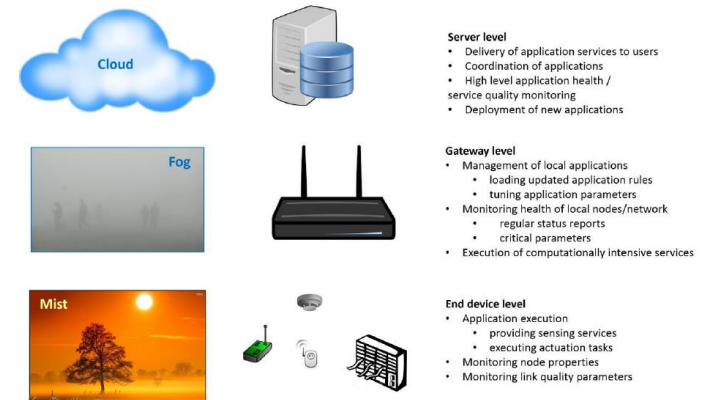 - Dew Computing

Server level
- Delivery of application services to users
- Coordination of applications
- High level application health / service quality monitoring
- Deployment of new applications

Gateway level
- Management of local applications
  - loading updated application rules
  - tuning application parameters
- Monitoring health of local nodes/network
  - regular status reports
  - critical parameters
- Execution of computationally intensive services

End device level
- Application execution
  - providing sensing services
  - executing actuation tasks
- Monitoring node properties
- Monitoring link quality parameters

mDC with small cells

QCOM's Small Cell

Downlink	~110 Mbps
Uplink	~15 Mbps
RTT	~10 msec

Dew Computing Research
The clouds let drop the dew

DEWCOM 2016 Held in Charlottetown

Candidates for Edge Computing

☐ MEC vs Fog vs Cloudlet

	MEC	**Fog**	**Cloudlet**
Communication between edges (Wireless Multi-hop)	No	Yes	No
Connection with Cloud	No	Yes	Yes, a little

❖ OpenFog and ETSI have recently signed MOU

"OpenFog Reference Architecture will extend the mobile edge with a physical and logical multi-layered network hierarchy of cooperating fog nodes that interface between cloud and edge, allowing for interoperability across operators."

OpenFog News & Events / News, 25th Sept. 2017

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ICN over Edge Computing (1)

ICN

Naming

Forwarding & Routing

Caching

Content Security

Edge

XaaS

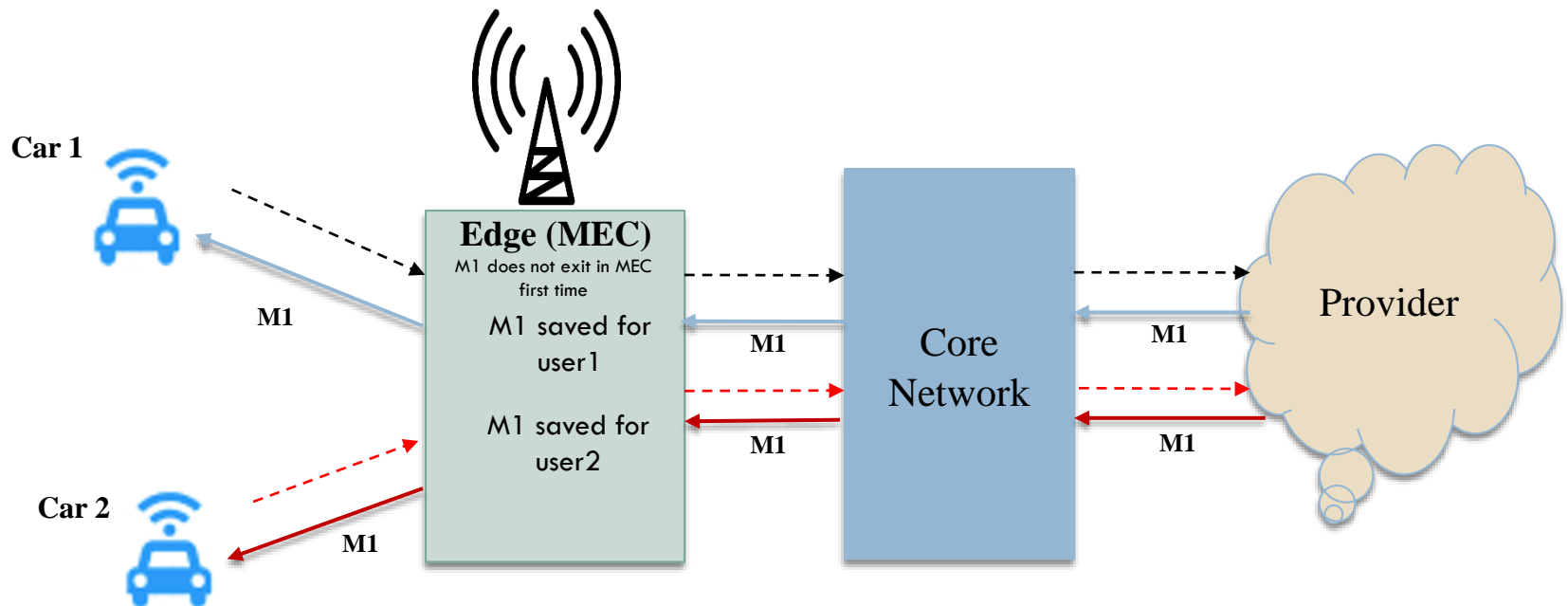**Radio Network Information Services**

Traffic Offloading
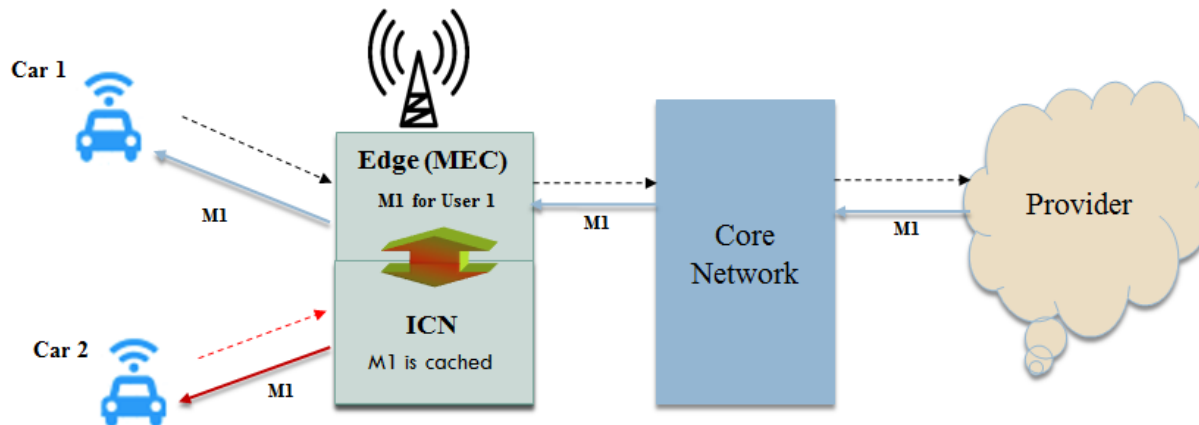
Low Latency

ICN over Edge Computing (2)

☐ Content Delivery with only Edge

ICN over Edge Computing (3)

☐ **Content Delivery with ICN + Edge : Caching**

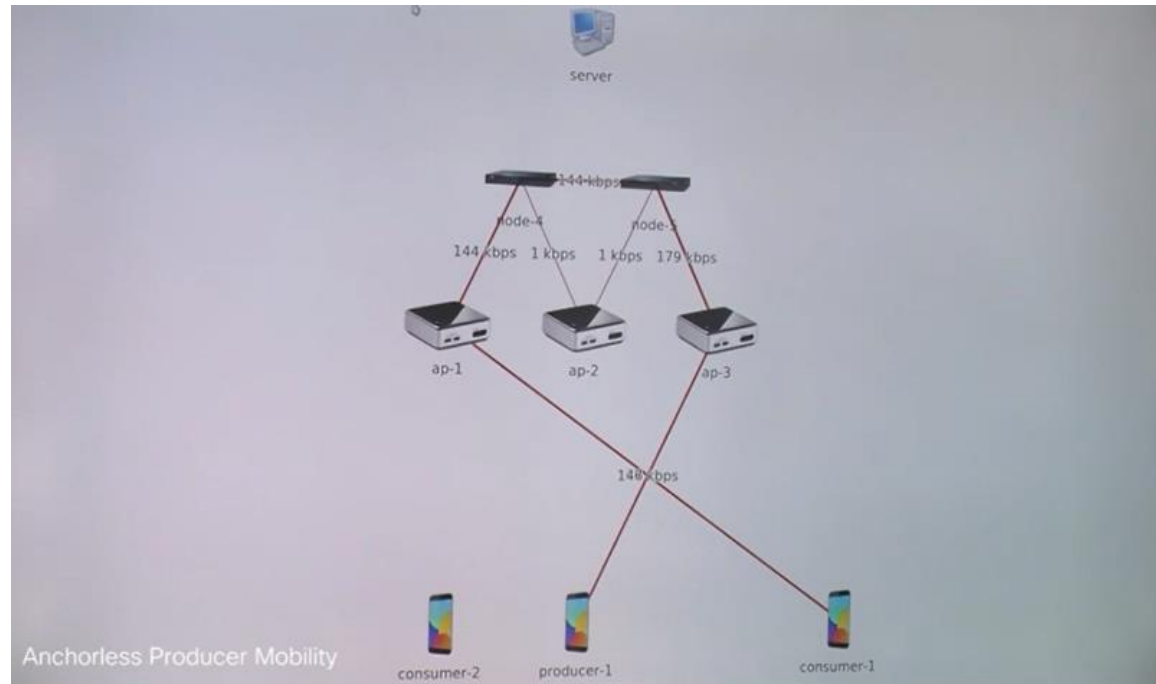

☐ Cache-Management over ICN + Edge
- ☐ How to merge Edge and ICN?
- ☐ Where is the content stored? Edge-Storage or ICN-Cache
- ☐ Does it need to be stored in both?
- ☐ How to mange contents in Edge & ICN-Cache? Can a content be shared with others?
- ☐ Does Edge can be a provider of ICN?

ICN over Edge Computing (4)

□ ICN + Edge : Inter-Communication between Edges

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CCN + Edge Computing Project

- Content-Based Mobile Edge Networking (CBMEN)
  - Sponsored by DARPA
  - To design the network services and transport architectures to enable efficient, transparent distribution of content in mobile ad hoc network environments.
  - Key Features
    - Routing and forwarding on disrupted mobile networks based on connectivity modeling and network coding;
    - A highly expressive content advertisement and querying-enabling discovery and collaboration on a distributed, tactical edge Semantic Web;
    - A robust, fine grained security and access control via functional encryption mechanisms.
    - Distributed content location and sharing over a mobile ad-hoc network on Android devices.

http://www.darpa.mil/program/content-based-mobile-edge-networking

BcNLab at Hongik University
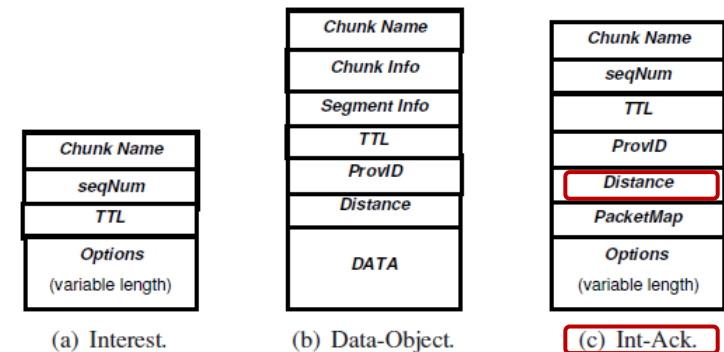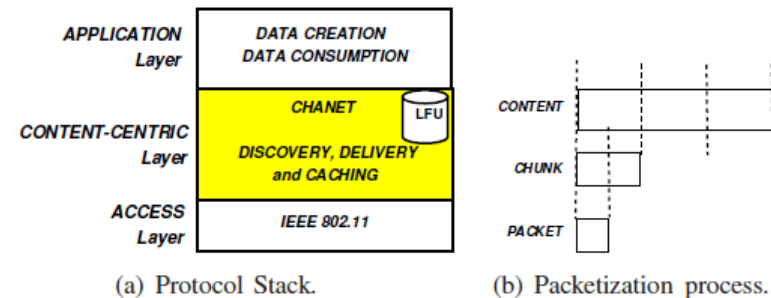
CCN over Wireless vs. Wired Networks

- ☐ Lossy channel & Broadcast nature ➔ Reliability Issue
    - ❑ Retransmission?
    - ❑ Flooding?
    - ❑ Collisions & overhead?
    - ❑ Complete content might not be stored

- ☐ Mobility, Battery Constraints ➔ Varying Topology and frequent leave/join of node
    - ❑ Hierarchical Naming? Naming-based Forwarding?
    - ❑ Routing required?
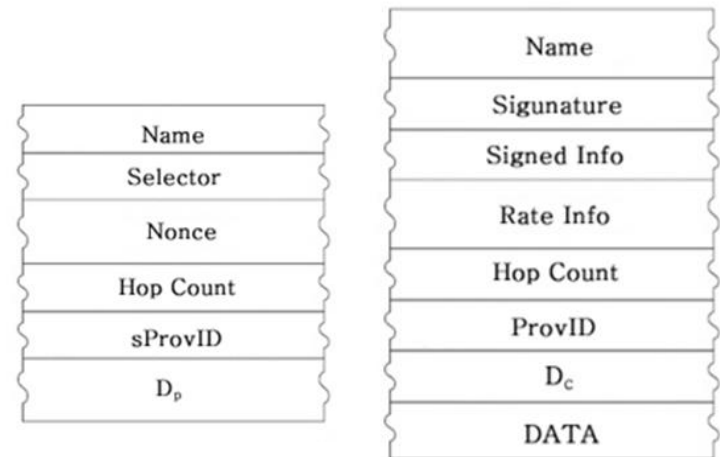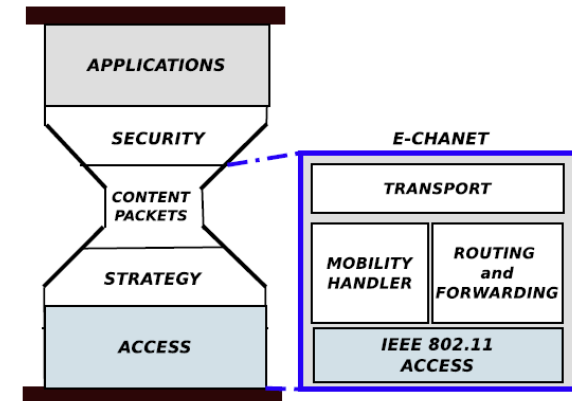   - ❑ Provider Handoff
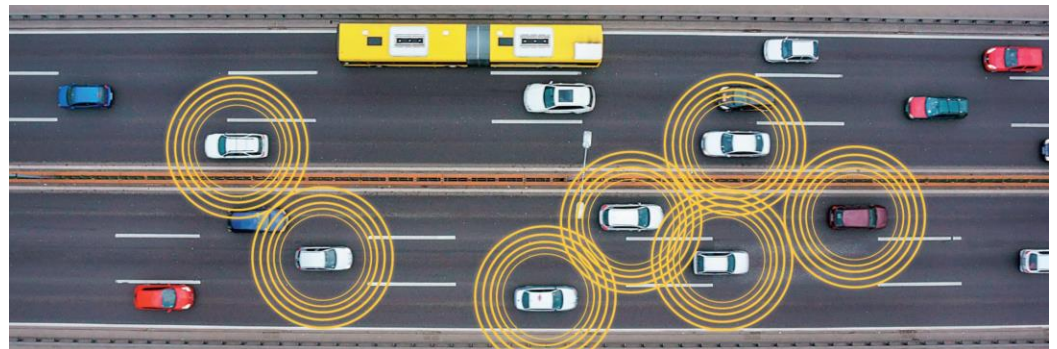
Wireless CCN – CHANET (1)

- Content centric fasHion mANET (CHANET)
- Based on IEEE802.11
- No FIB
- Content Naming = Unique ID
- Components
  - CoS(=CS), PIT, CPT*(Content Provider Table)*
- Interest-Data-Int-Ack Handshaking
  - Interest for the first request
  - Int-Ack for subsequent request and ACK for the previous Data.
- Defer time: to prevent from collision
- seqNum & TTL
  - to prevent from loop
  - Distance-aware forwarding

(a) Protocol Stack.   (b) Packetization process.

(a) Interest.   (b) Data-Object.   (c) Int-Ack.

M. Amadeo , A. Molinaro , CHANET: a content-centric architecture for IEEE 802.11 MANETs, in: Network of the Future (NOF), 2011 International Conference on the, IEEE, 2011, pp. 122–127 .

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Wireless CCN – ECHANET (2)

- Enhanced CHANET

- Components:
  - CS, PIT, FIB (for different wireless techs), CPT

- Interest-Data Handshaking

- Transport
  - Interest Retransmission using RTO
  - Control Interest transmission rate

- Mobility Handler
  - Consumer-driven handover
  - Provider-driven handover

- Distance-aware forwarding

M. Amadeo , A. Molinaro , G. Ruggeri , E-CHANET: routing, forwarding and transport in information-centric multihop wireless networks, Comput. Com- mun. 36 (7) (2013) 792–803 .

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Conclusion

☐ ICN + Edge computing might be a way to go for vehicular networks!

☐ Roles of ICN and Edge Computing are not overlapped, but there are synergies to be exploited.

☐ Need to deep dive for ICN + Edge

Thank You!