Ubiquitous Witness in the Visual Fog

(aka Multi-dimensional Anomaly Reconstruction or 360-degree "Blackbox")

Eve M. Schooler (NGS), *Maruti Gupta (IL), Hassnaa Moustafa (ADG)*

ICN Use Case Discussion

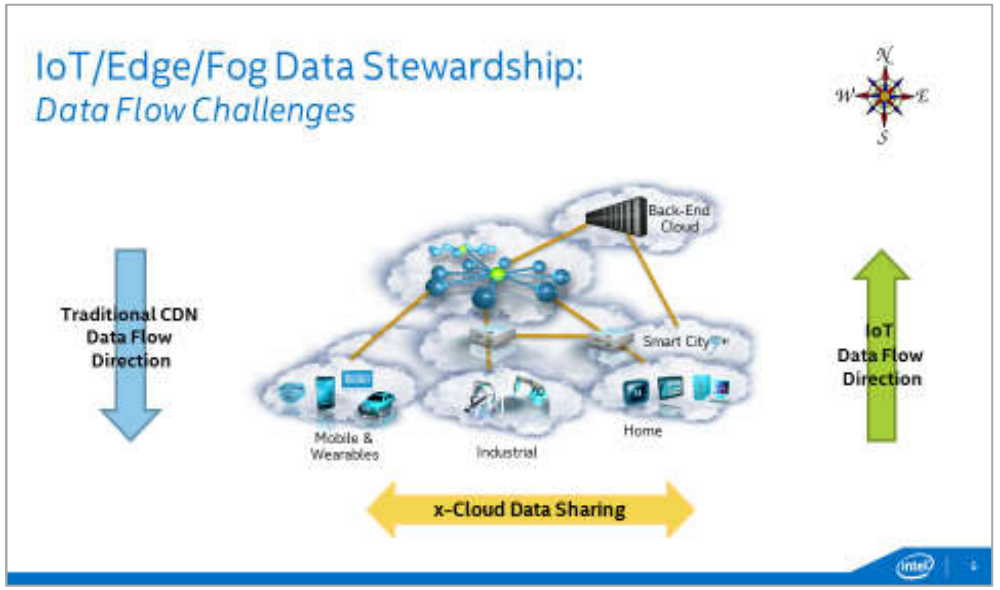
July 17, 2018

Discussion

- Backdrop
- Use Case
- Why it is Interesting
- Why it is Challenging

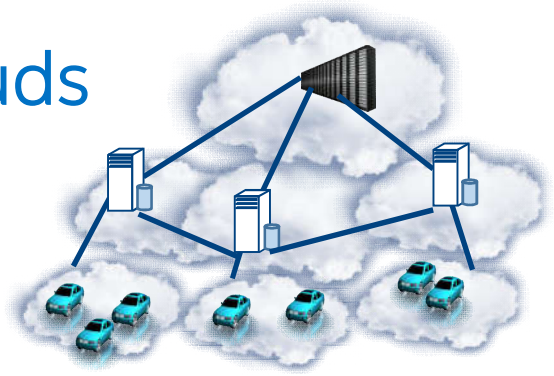
Backdrop

- IoT disruption: sheer #s of devices → data deluge at the network edge
- Increasing percent of Things: wireless/mobile
- Increasing percent of Things: are or include cameras
- Edge computing: part of bigger trend toward Fog & Ambient computing



Leverage ICN for Edge/Fog Comms: N/S, E/W, intra-cloud

An ICN-based Multi-tier Cloud of Clouds



Leverage ICN for Edge/Fog comms [9][4]

- **N/S:** *Video Analytics (Surveillance), Visual Fog*
  - Enable e2e reverse flows (N-to-1) – rCDNs [6][5][3]
  - Enable Converged Edge/Fog nodes – rCDN nodes
- **E/W**: *Industrial IoT, Smart Cities*
  - Liberate/Unify access to Data across “silos”
- **Intra- and Inter-cloud:** *Standards eco-system*
  - Interoperability – Re-use meta-data across layers [1]
  - Discovery services – Find data, meta-data, services, ontologies/vocabularies, directories of directories, trust anchors/brokers

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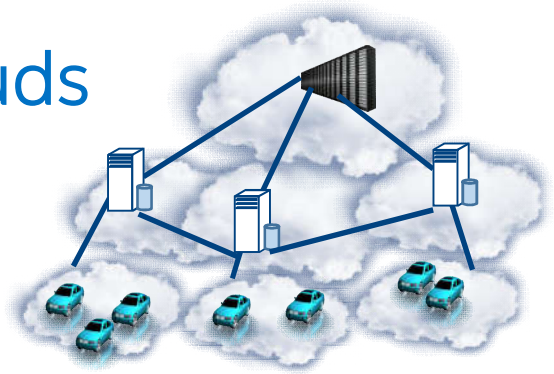

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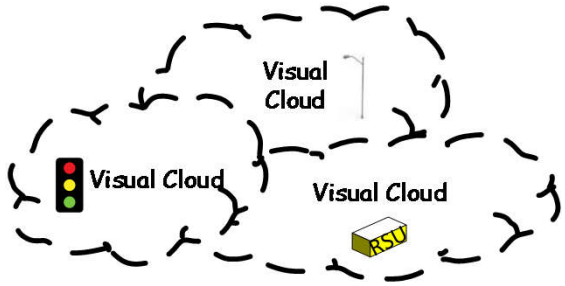
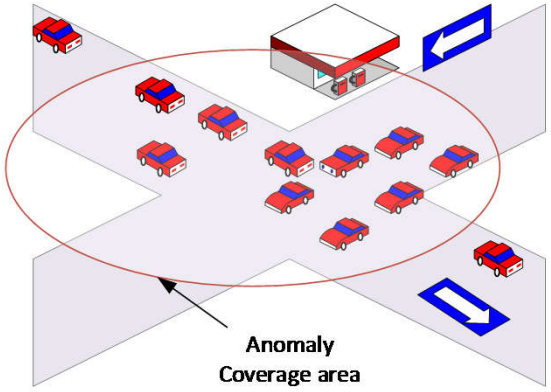
Use case: Ubiquitous Witness in the Visual Fog

Multi-dimensional Anomaly Reconstruction

- Anomaly detected (or predicted)
  - *e.g.,* an accident occurs
- Triggers secure (video) evidence collection from proximate witnesses
  - directly involved & nearby observers
  - ICN – with vs without
- Data collected and securely stored in 360-degree "black box"
  - composite from multiple perspectives within an approximate region of interest, e.g., <x,y,z,time>
- Post facto, enable exploration of multi-dimensional evidence
  - leverage point-cloud VR standards





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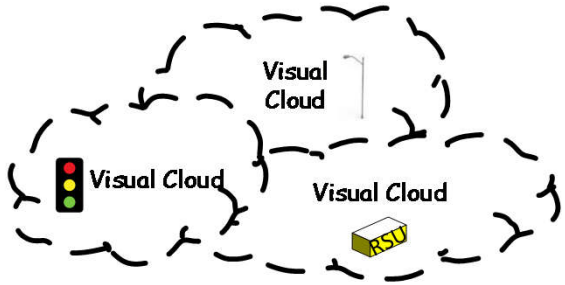
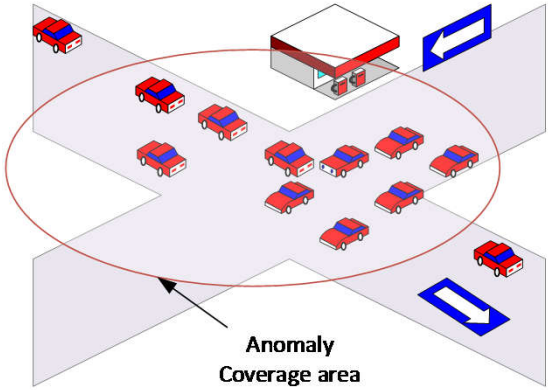
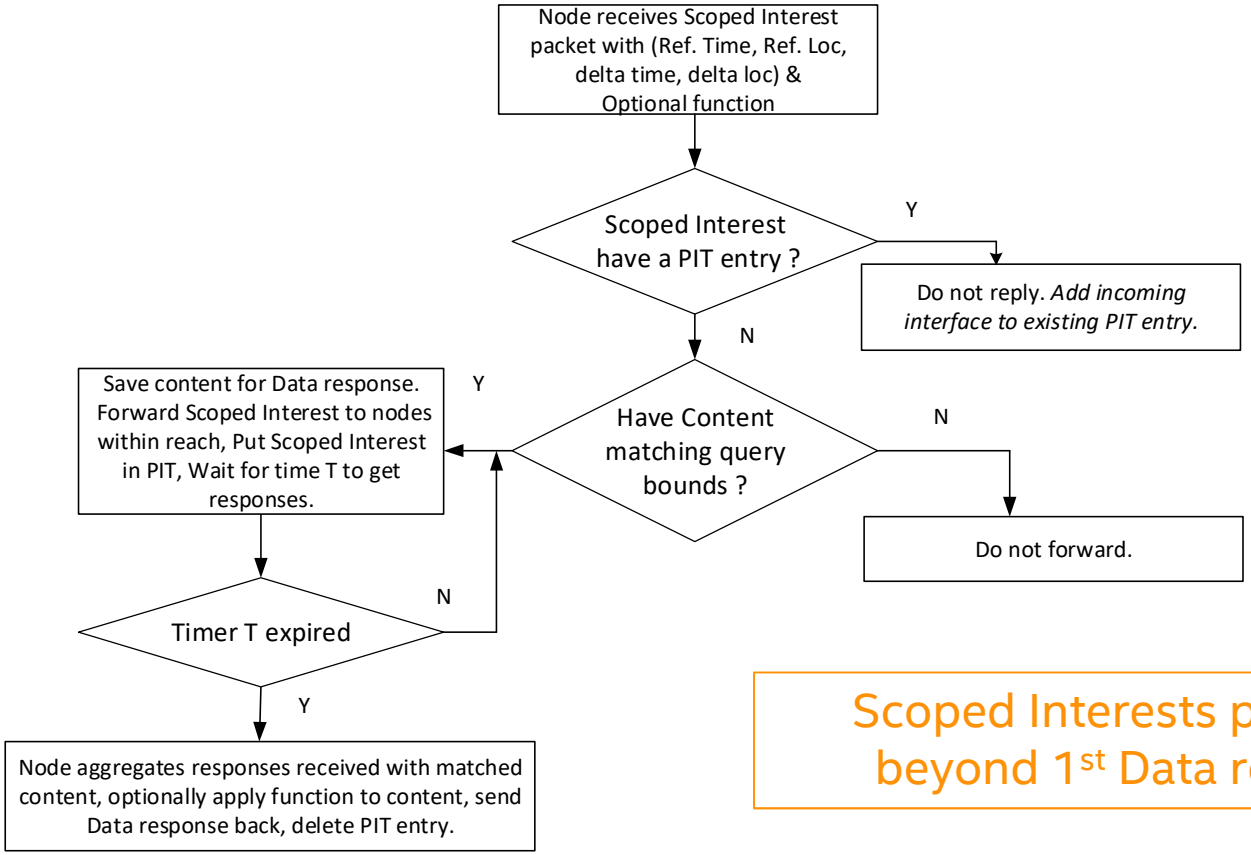




Why it is Interesting yet Challenging:
Extend ICN Semantics?

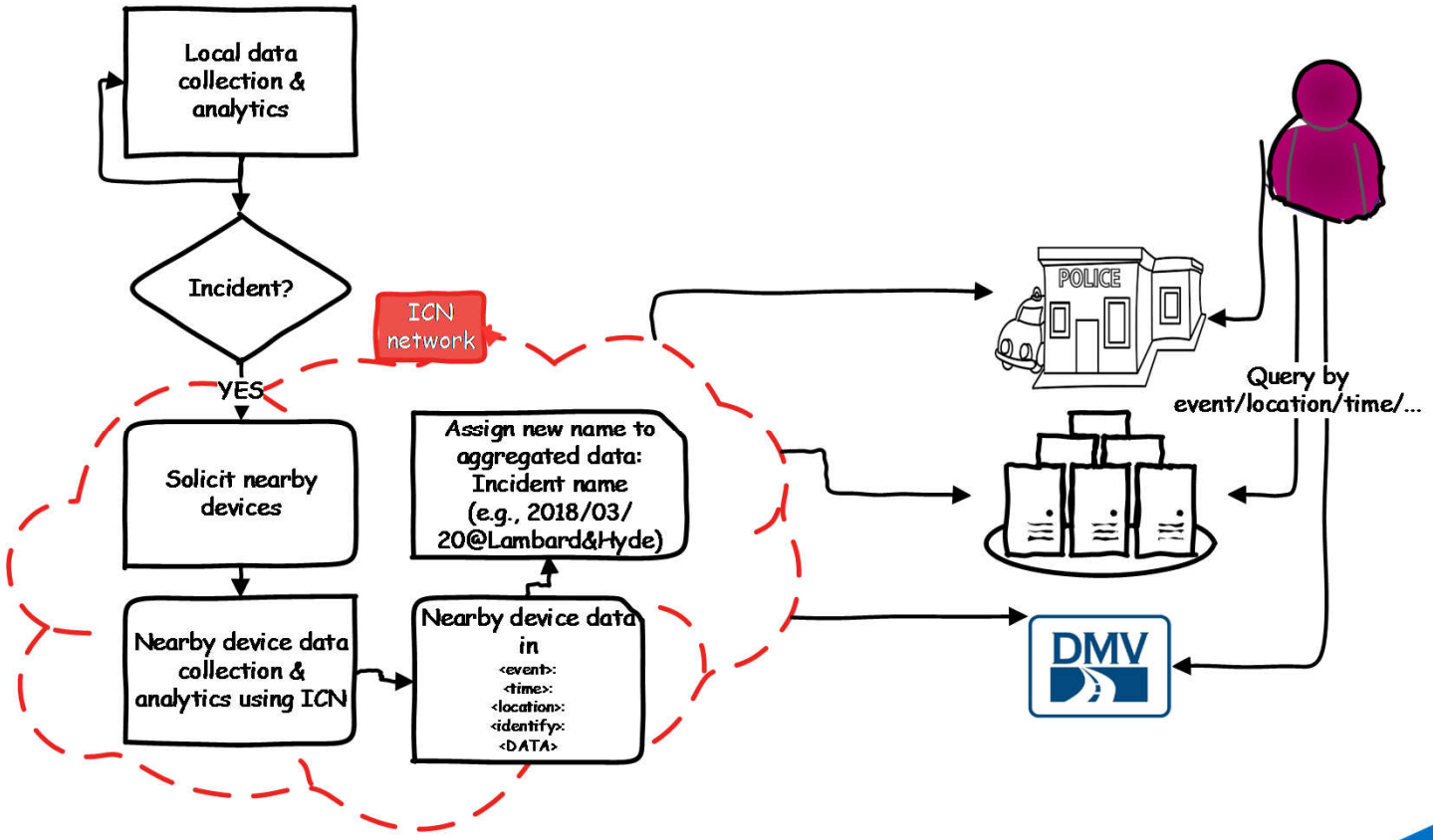
- Fuzzy names
  - <x, y, z, time> + or – some delta
  - Longest prefix match vs Exact match
  - HD Maps: GeographicalLocation/Date/Timestamp/Entityname
- “Scoped Interest” dissemination
  - Delayed Responses
  - Embedded Functions
- Congestion control
  - Identify who to solicit – explicit vs implicit
  - Who issues the request? Who is authorized? ICN vs IP
  - Collapse requests/responses within coverage area & time deltas

Scoped Interest-Data Semantics

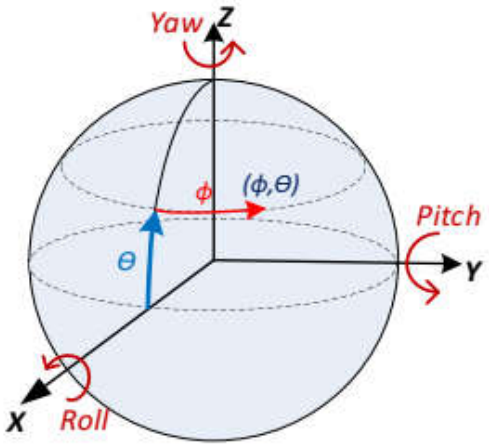


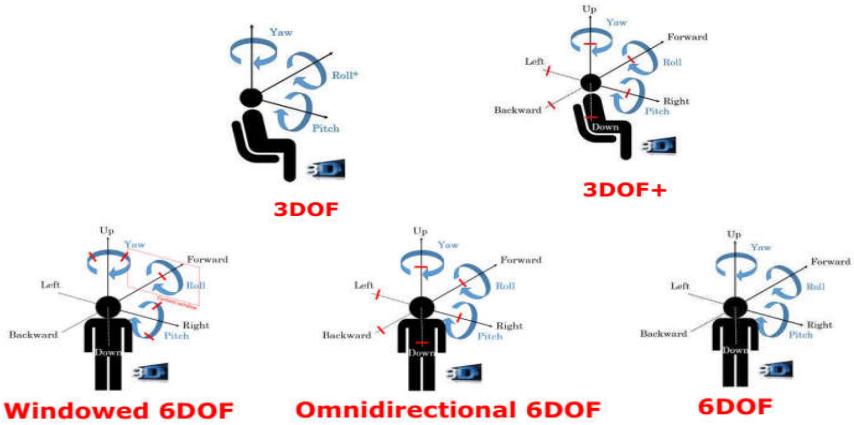
Scoped Interests propagate beyond 1st Data response

Query (ICN-enabled) Network as if a Database



Emerging MPEG-I VR Standards:
3- and 6-Degrees-of-Freedom (DOF)





Want to “walk around” in the data… whether visual or non-visual

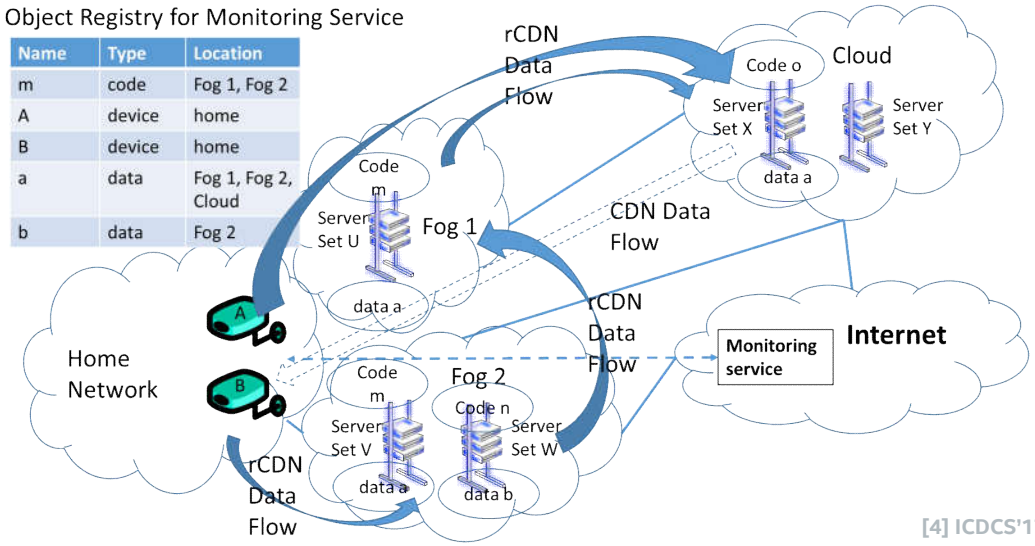
Source: Ozgur Oyman VR Tutorial

BACKUP

Enable the Reverse CDN (rCDN):

Reverse data flows combining routing, caching and processing

Traditional CDN Data Flow Direction



[4] ICDCS'17

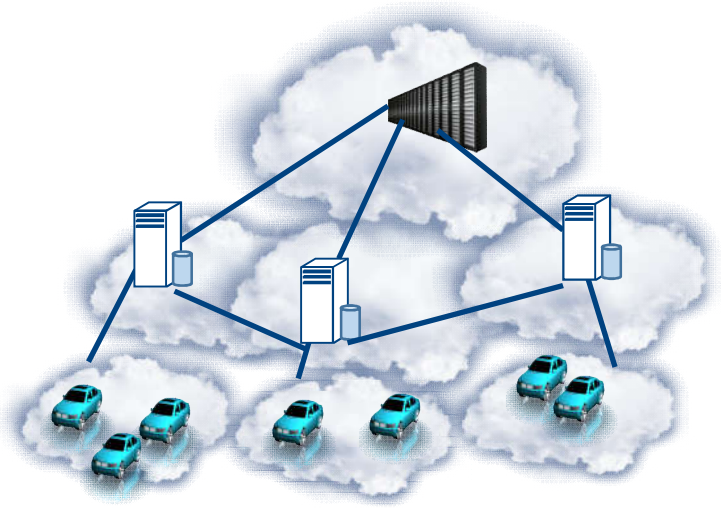
IoT Data Flow Direction

Exploit ICN to pin routing, caching and processing in **optimal places**

Video rCDN: Anatomy of a Converged Edge/Fog Node

Lifecycle of Reverse Data Flows

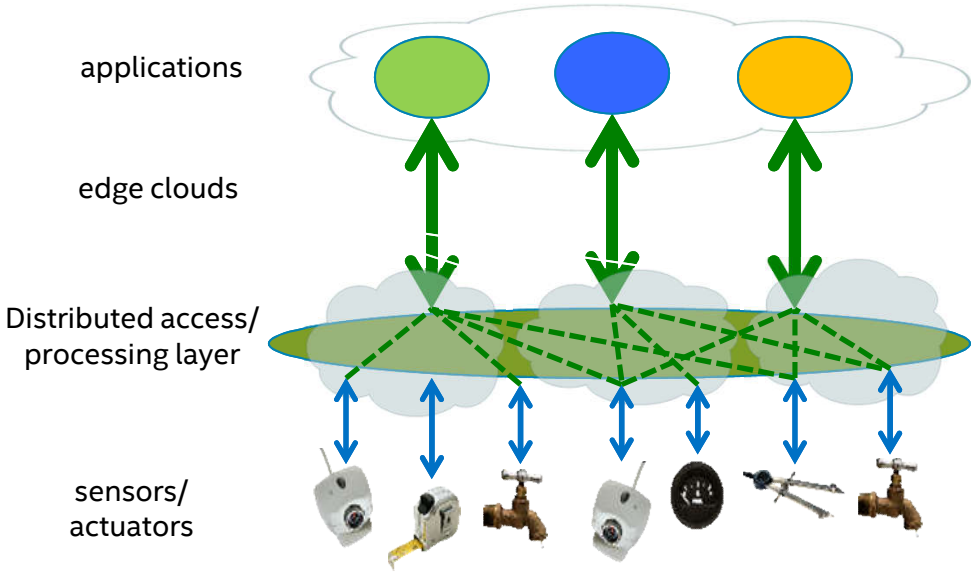
- Client devices act as data sources
- Dynamic **contextually-related** data flows upstream/reverse - & collect at rCDN nodes
- **Process/transform/analyze/combine** data into new stream (w/reduced size) **in-flight**
- **Converge (N-to-1)** streams into a single new one
- Preserve lineage
- Deliver precise **synchronization**
- Decide how/where to **cache** new converged (meta) data stream
- **Forward** N, but possibly S, possibly E/W too
- Process potentially **repeats multiple times,** while data "en route" to final resting place



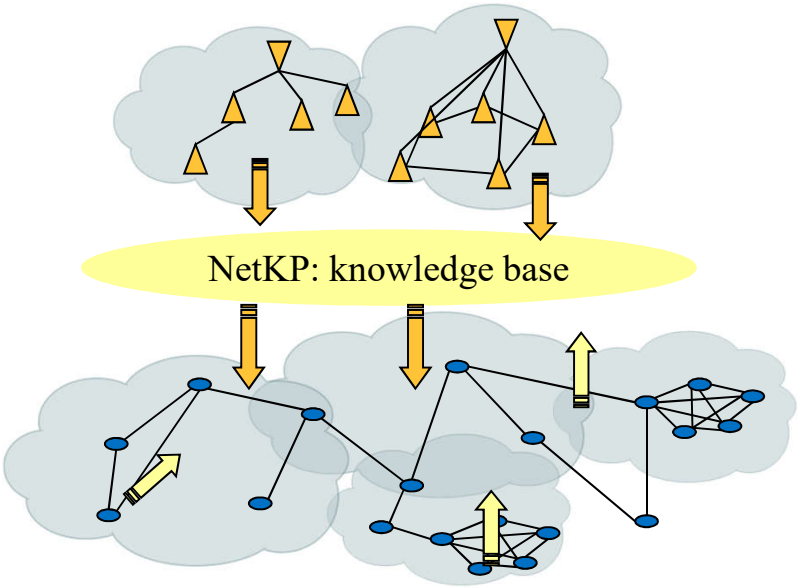
Connected & AD Vehicles in a Smart City

Is each rCDN node a new Converged Edge/Fog router? At what layer should it live?

Liberate/Unify access to Data across “silos”:
The Knowledge Plane



Source: Ken Calvert ICNP'16



Source: Adapted from Karen Sollins NetKP project

Acknowledgment

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8. Andrew Brown et al, "Information Centric Networking for IoT Devices", *Intel Software Professionals Conference*, demo & presentation (Aug 2015).
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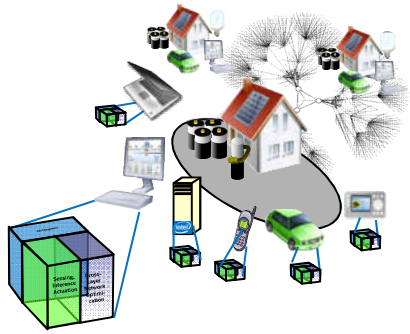
ICN for IoT at the Network Edge



- **Deployed in Trusted Local Clouds**
  - Sidestepped Internet-wide deployment issue
- **ICN as a Trusted Data Bus** - Built early IoT PoCs
  - **iHEMS:** Smart homes & energy – *Pub-sub & Security APIs* [13]
  - **iCity**: Smart neighborhood EV charging – *Data-centric privacy & mobile devices* [12][11]
  - **Updaticator:** Massive IoT software updates – *Scalability & security* [10][2]
  - **ICE-CP:** Smart "data pipes" (for trusted analytics) – *Move the compute to the data* [8][7][6]
- **ICN in Wireless Edge Networks** - Launched NSF-Intel ICN-WEN program
  - Examine lower-layer requirements & x-layer co-design
  - Enable Ultra low-latency and massive IoT applications in the face of Mobility

Evidence Solicitation Considerations

1. **Digital Witness Identification**
   - Parties involved directly
   - Digital observers of the anomaly
2. **Data Gathering**
   - ICN vs non-ICN
   - Edge vs Cloud
3. **Multi-dimensional reconstruction**
   - Variety of sensor data (image, audio, video, etc.)
   - Multimedia-appropriate processing algorithms
   - Time-synchronized input

Visual Cloud to Edge to Fog:
Video Storage/Processing

Interesting domain because…
- Static & Mobile infrastructure
- Many silos of data
- Multi-modal data
- Continuous & intermittent data
- Time-sensitivity

Cloud-only?

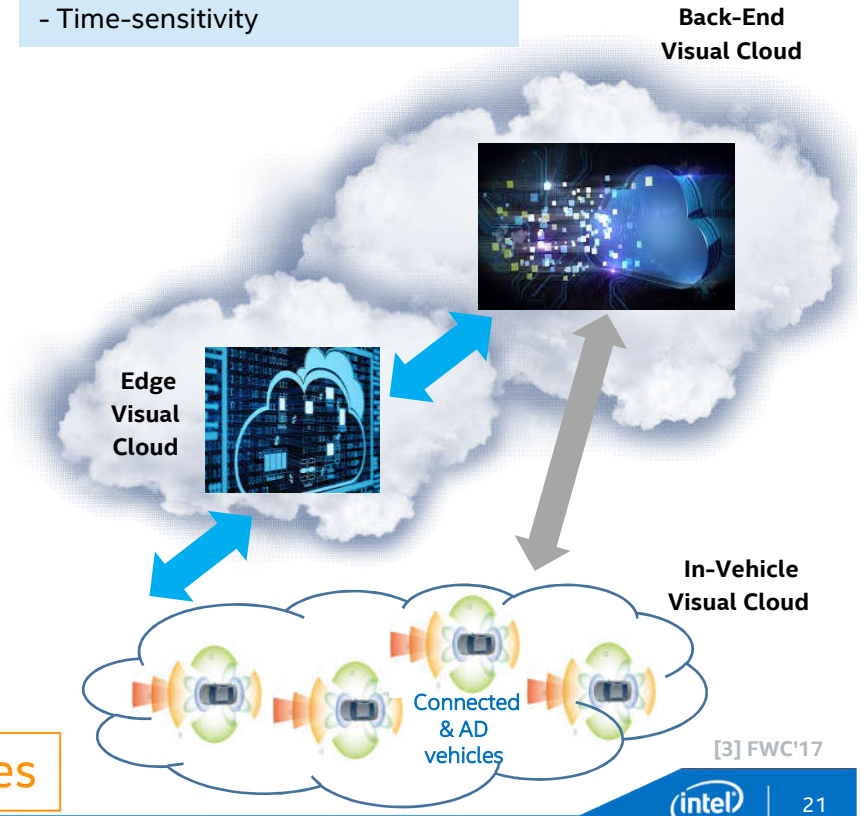
- ***Challenge:*** Huge amount of data generated by each car vs. network bandwidth (even with 5G), cost, real-time requirements

In-Vehicle-only?

- ***Challenge:*** Not enough in-vehicle compute, due to space, heat dissipation, and cost of executing heuristics or AI needed

Distributed from Car-to-Cloud?

- ***Challenge:*** Storage efficiencies of CDN (Content Delivery Network) model helpful, but need to comprehend reverse data flows

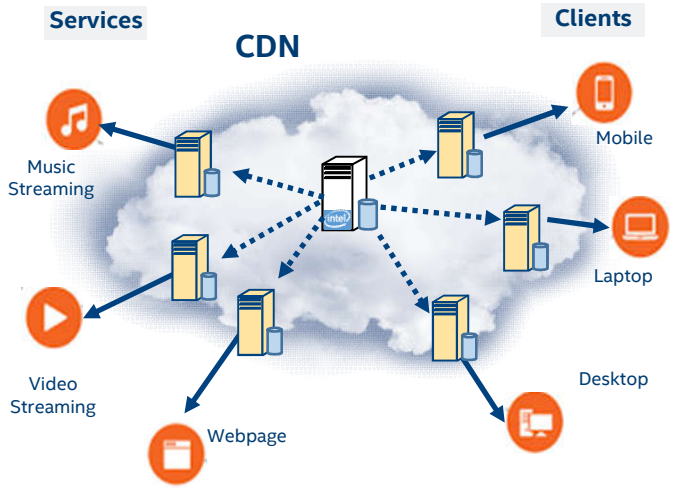


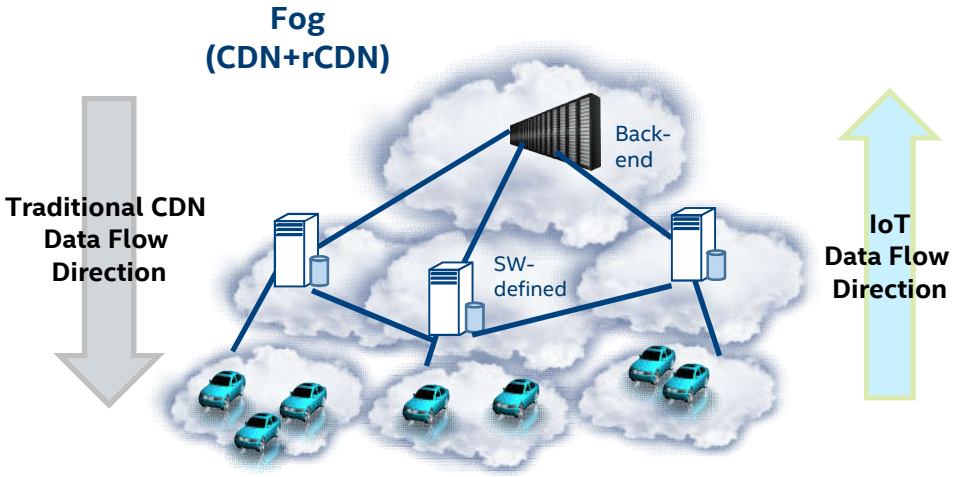
[3] FWC'17

Seamless interoperation of static & mobile Edges

Video CDNs & reverse CDNs (rCDNs)

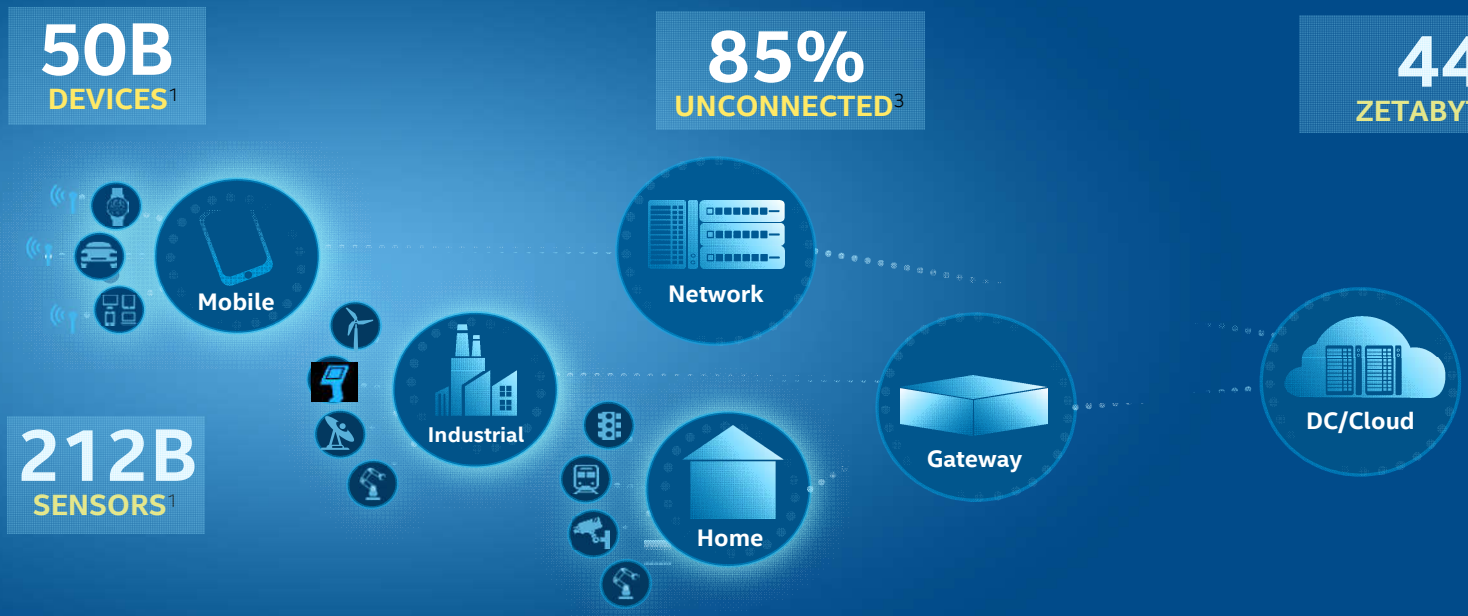
Content distribution networks





[3] Fog World Congress'17

The IoT …

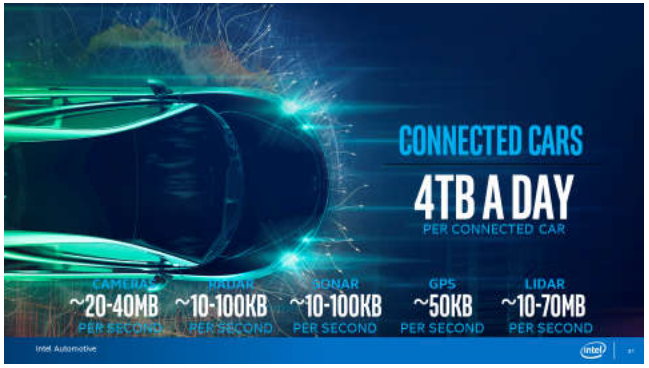


…changes our architectural thinking

1. IDC
2. MC/EDC: The Digital Universe of Opportunities
3. IMS Research

Disruption: Data Deluge

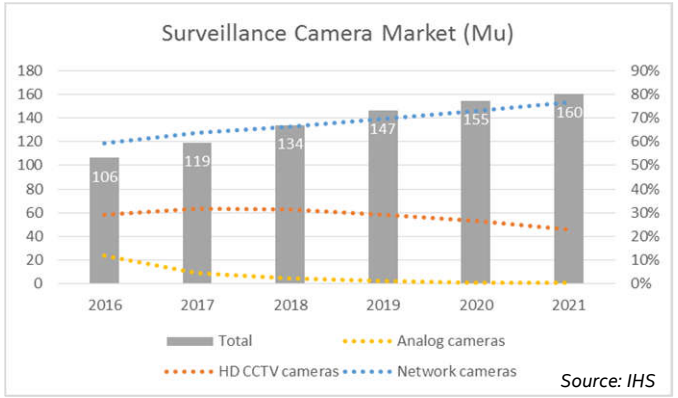
- **129 yottabytes** to be generated by 2020 *(ABI Research)*
  - *Deluge begins at the network Edge, flows upstream*
- **50%** of IoT deployments will be network constrained by 2018 *(IDC)*
  - *Data doesn't fit over the network, in its original form*
- By 2019, **45%** of IoT-created data will be stored, processed, analyzed and acted upon closest to, or at the edge of the network *(IDC)*
  - *Cloud functionality migrating closer to the data*



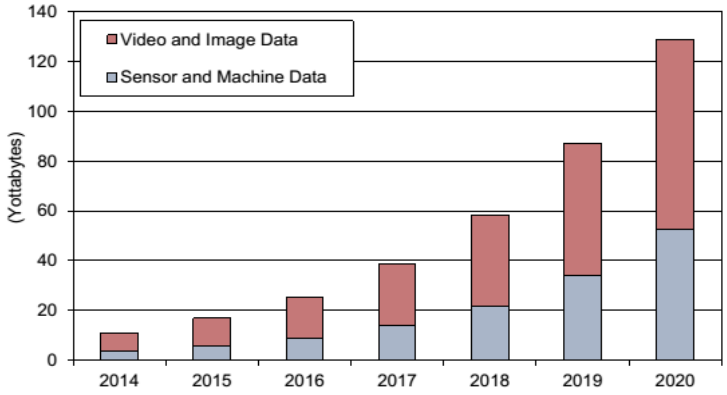
Cameras and Video

- By 2020, there will be 256M cameras on the planet. One camera for every 29 people *(IHS)*
- The number of cameras grows by 20% every year *(IHS)*
- 180/360-degree IP network cameras are the fastest growing product segment in video surveillance (*IHS*)
- Of the 129 yottabytes forecasted to be generated by 2020, 41% will come from sensors & 59% from cameras (*ABI Research*)

Coming to an intersection near you?



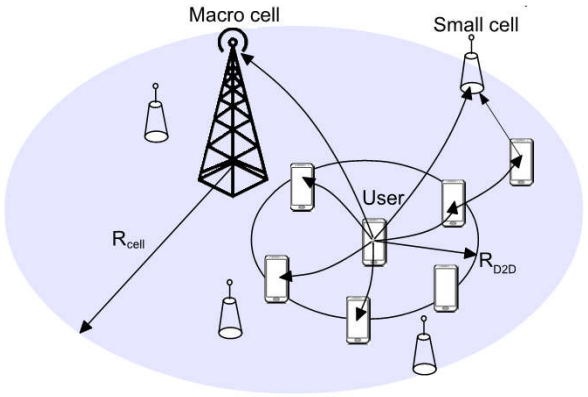
Source: IHS



Source: ABI Research

Wireless and Mobility

- By 2020
  - .5 Zettabytes mobile wireless traffic annually
  - 800x 10 years ago, 800Mx 15 years ago
- By 2021
  - 11.6B mobile devices >> fixed hosts
  - 63% of all traffic



Assumptions

- 5G high-bw usages: VR/AR, (ultra) HD video
- 5G architecture: dense HetNets, frequent small-cell handover

Toward Edge Computing... and beyond

Distant Cloud Problem:

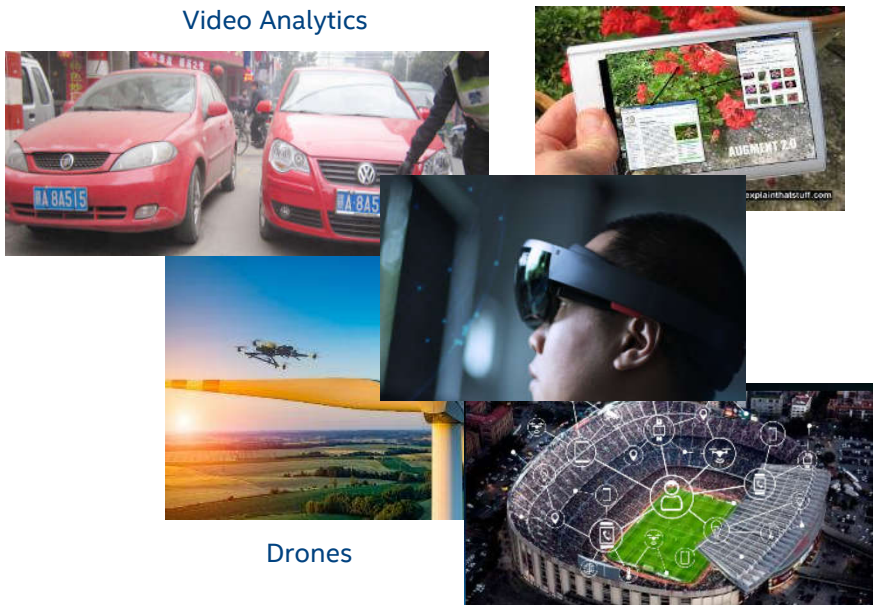
Legacy clouds are unsuitable for many IoT scenarios

If the IoT use case / data is

- High-volume
- Delay-sensitive
- Trust-sensitive
- (Intermittently) Disconnected
- Energy-constrained

Countless examples

- Both near and further out



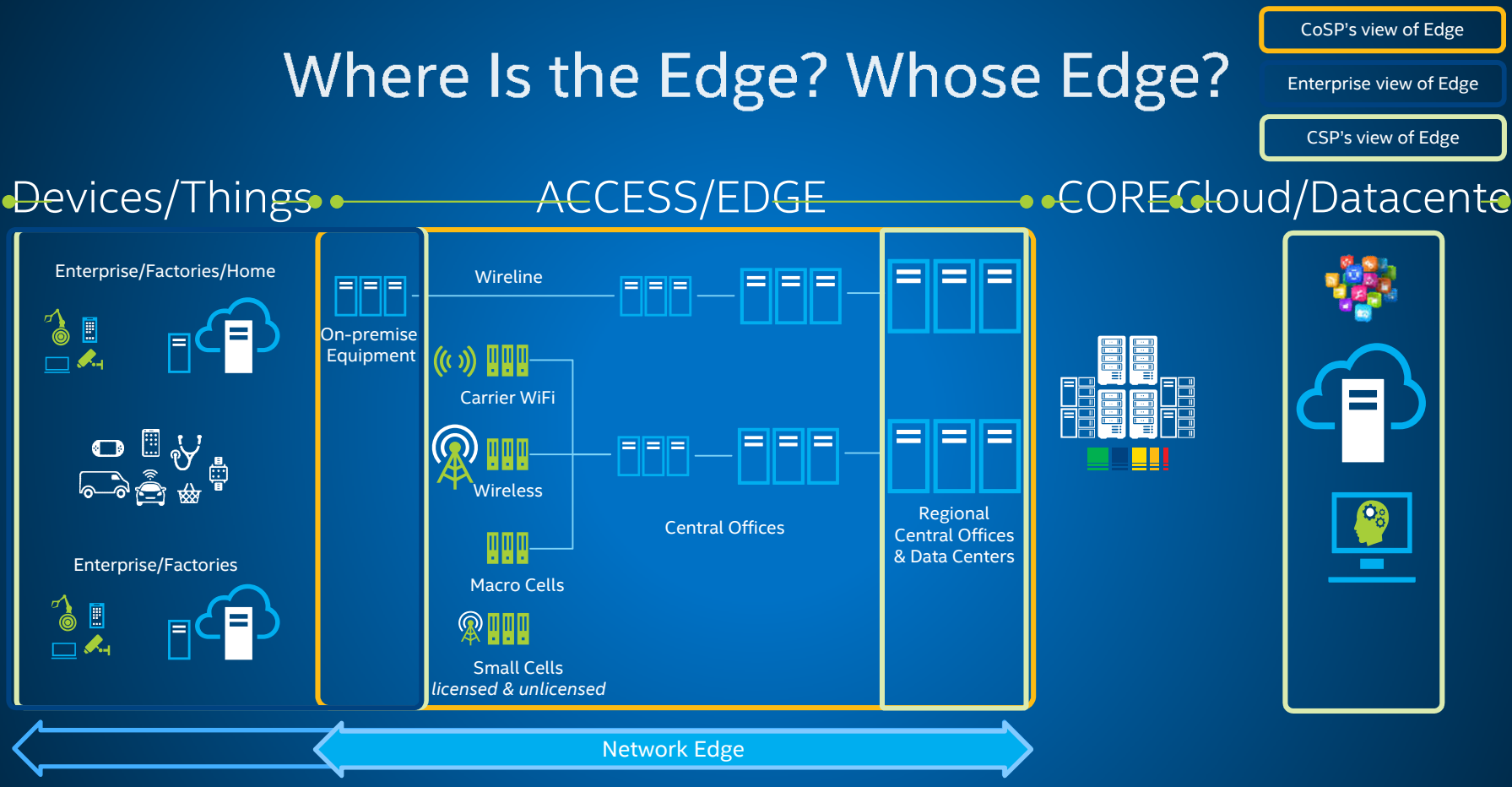
Need More Proximate Clouds: Edge Computing

Where Is the Edge? Whose Edge?

CoSP's view of Edge

Enterprise view of Edge

CSP's view of Edge



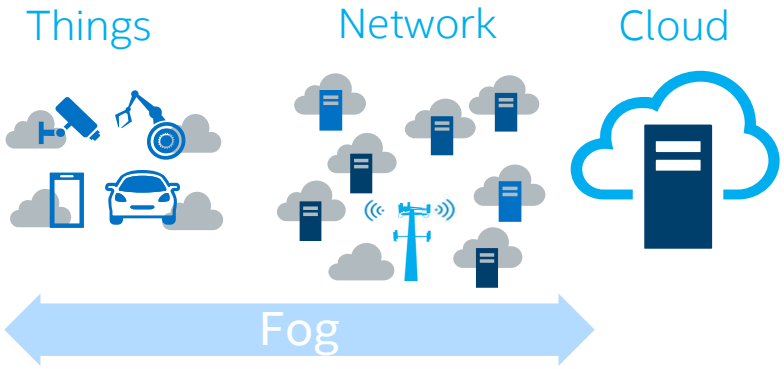
Edge Computing

Not in the Legacy Data Center

- Cloud functionality migrates closer to data creation, processing, & decision-making
- Where is the network Edge? Who owns it?
- An Edge offers an “Edge Cloud” - for more proximate HW, FW, SW, Services
- $B new business opportunity - distinct from Cloud

Fog Computing

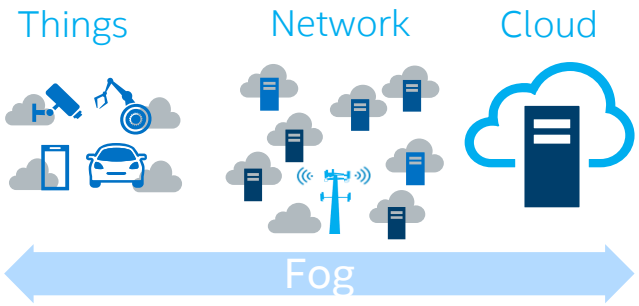
Disaggregated Data Center



- Proliferation of Cloud offerings
- Distributed, Disaggregated DC Functionality
- DC of the the Smart City, Building, Home, Car, DC of your Mobile & Wearable Devices
- Dynamic sharing of resources

Evolving Definitions:
Still up for debate…

- Cloud, Fog, Edge…Ambient computing are part of a continuum…
- Edge/Fog "Computing" encompasses more than compute



- Fog will become a Multi-tiered Cloud of Clouds