

Fog

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From Cloud to Fog



2000 – 2015



2016 – 2030 ?

What is “Fog”?

- An **architecture** that uses one or a collaborative multitude of **end-user clients or near-user edge devices** to carry out a substantial amount of **computation, storage, communication, and control** (& configuration, measurement and management)
- Distribute computation, storage, communication and control services immersively closer to end-users along the **Cloud-to-Things (C2T) continuum**

What is “Architecture”

- **Modularization:**
 - Who does what, at what timescale, and how to glue them back together
 - Allocation of functions, not resources
- **Successful cases:**
 - Source-channel separation: Digital communication
 - TCP/IP : Internet applications
 - Fog : ?

Many Types of Edge/Client/Things



Contrast Them With...



ZXUN xGW V4 convergent packet gateway

Client/Edge/Things

- Are recently becoming
 - Powerful (in sensing, storage, computing, control, comm.)
 - Still limited (in battery, storage, computing, information)
 - Maybe mobile
- Crowds of clients/edge devices are
 - Dense
 - Distributed and immersive
 - Under-organized

Now Feasible and Interesting to Ask:

- “Can ‘this’ be done at clients/edge?”
- The set-top box in your living room replaces the DPI box?
- The dashboard in your car is your cloud caching content?
- Your phone (and other phones) become LTE PCRF?

Rather Than...



LTE Core
(for control)



Data Center
(for computation & storage)



Wide area network
(for communication)

Traditional View



use



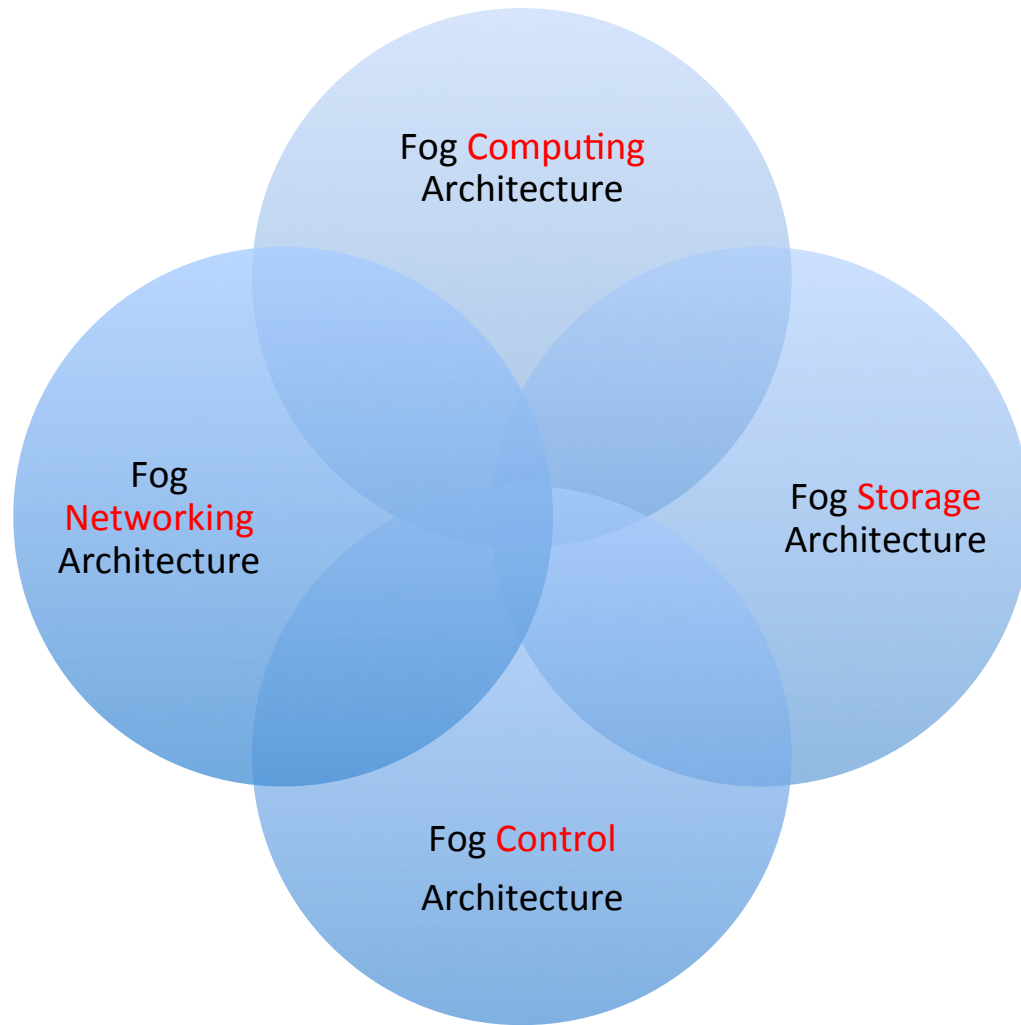
Fog View



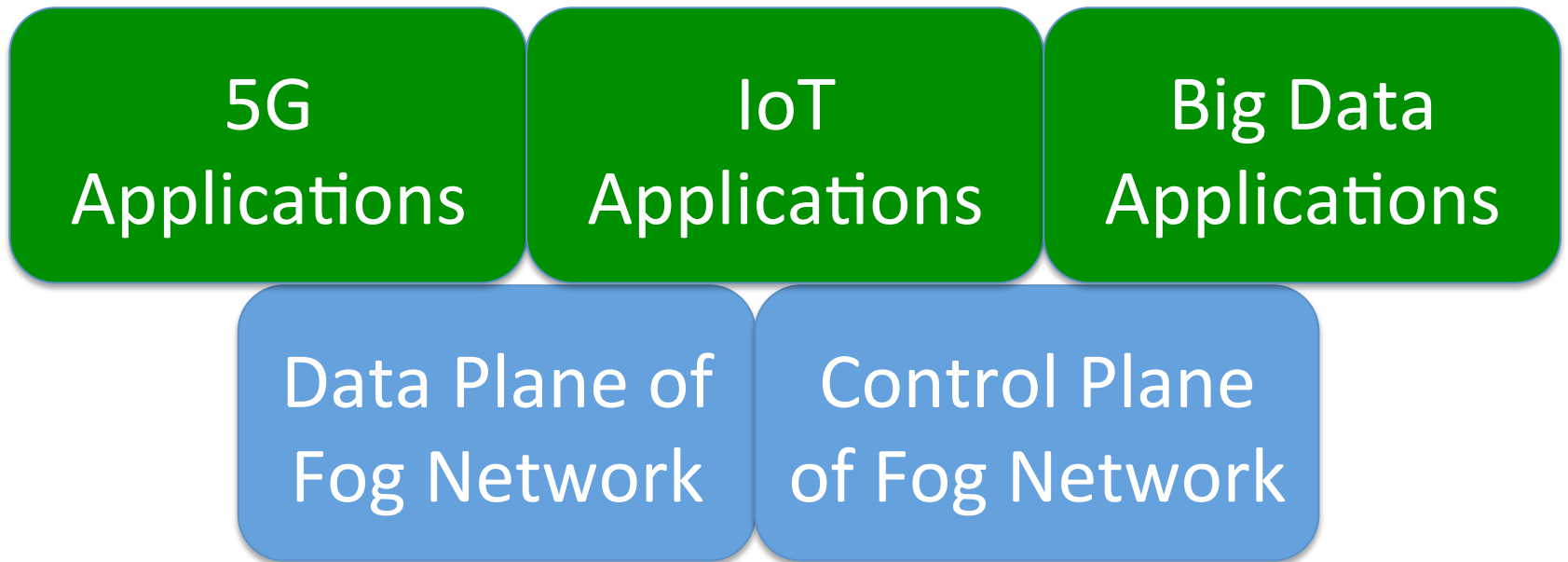
are (part of)



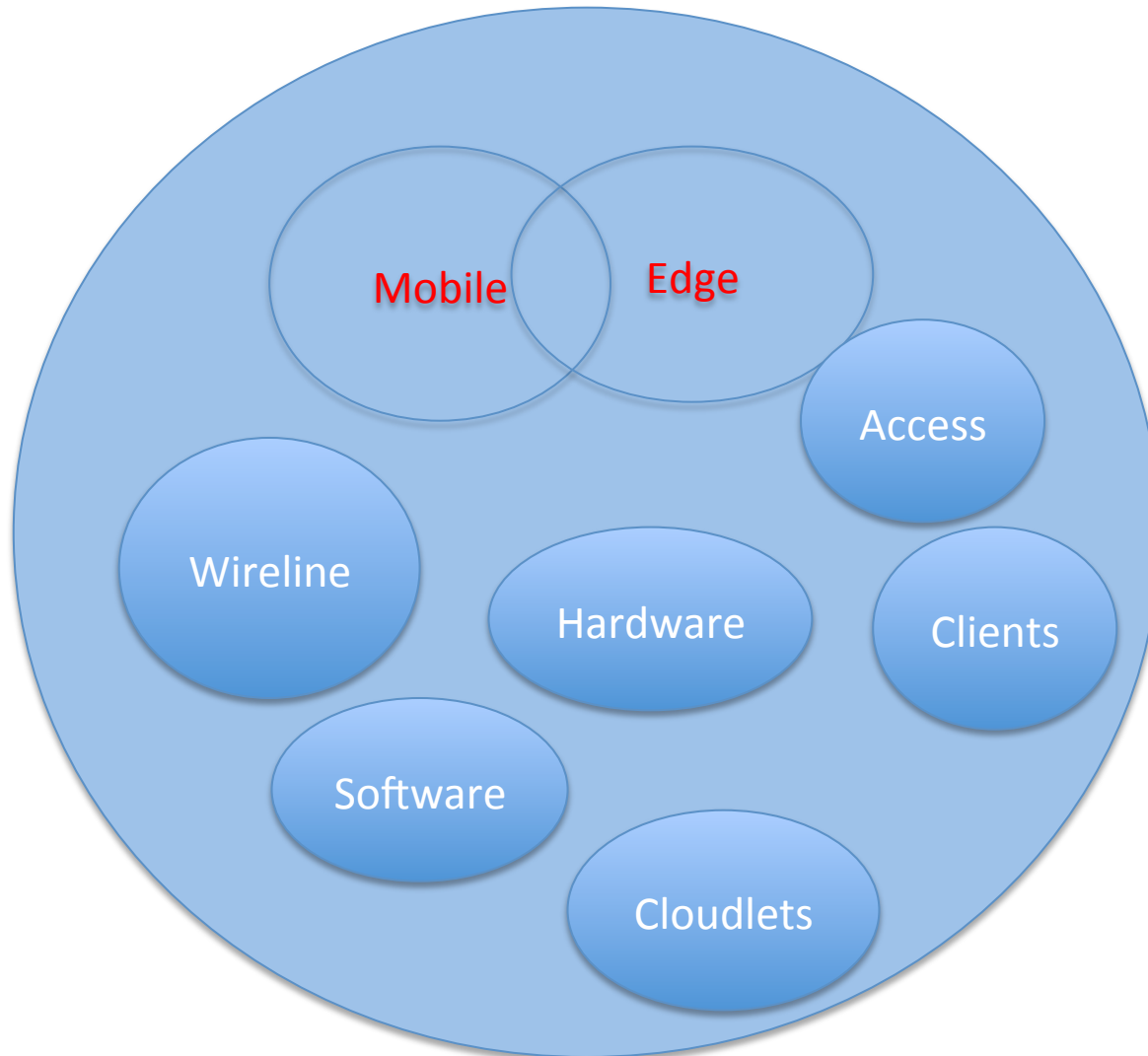
How Many Fogs?



Fog as a Network Architecture



Key Special Cases



Why Fog? CEAL

1. Cognition

- Awareness of ambience and user needs

2. Efficiency

- Resource sharing in D2D and D4D

3. Agility

- Agile development interface

4. Latency

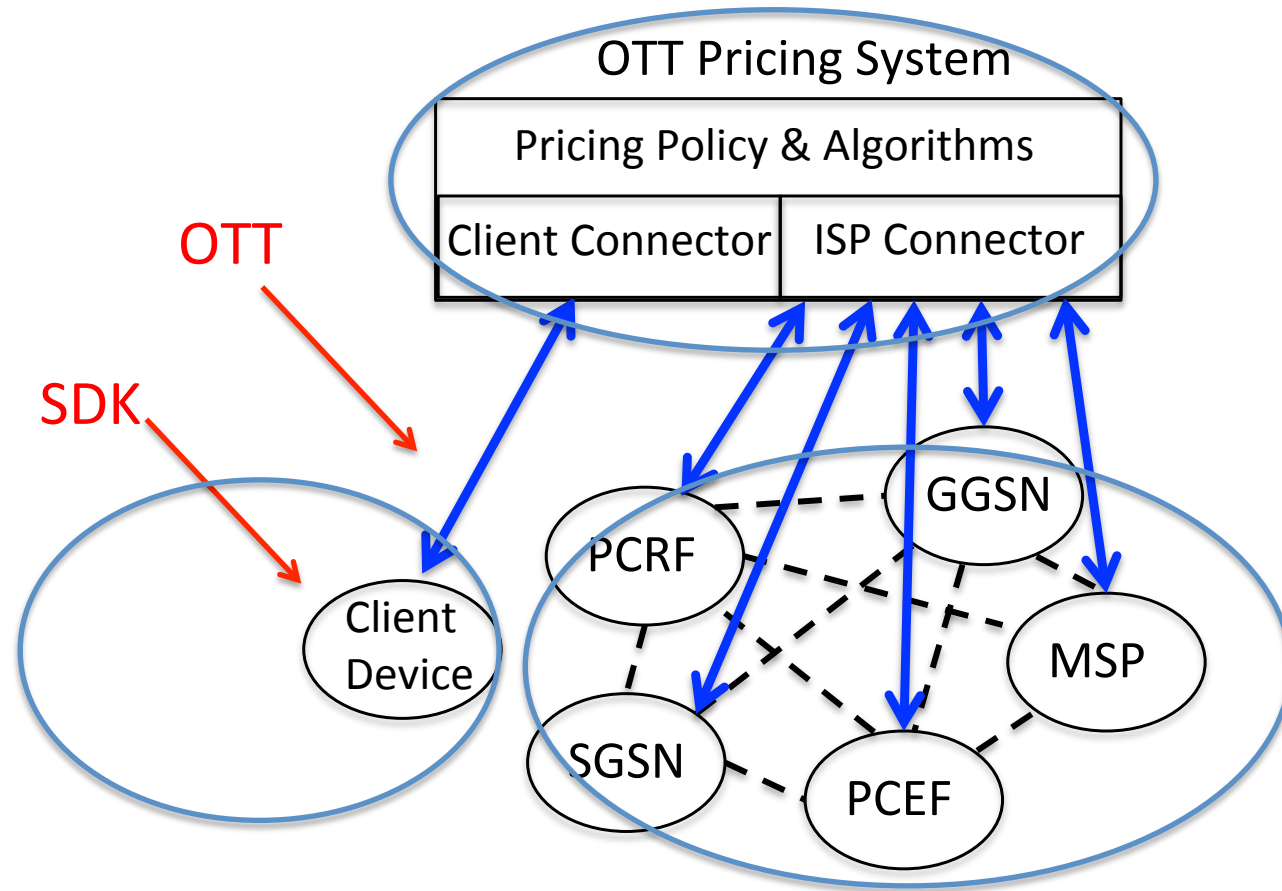
- Feedback loop in cyber physical systems
- Stream mining in edge analytics

Business Values

- Enable new services
- Broaden revenue base
- Accelerate rollout cycles
- Reduce cost
- Comply with regulations

Case 1: Smart Data Pricing

(in global deployment through startup DataMi)



Clients can crowd-source network inference/measurement and overlay billing

Fog-Cloud Interface



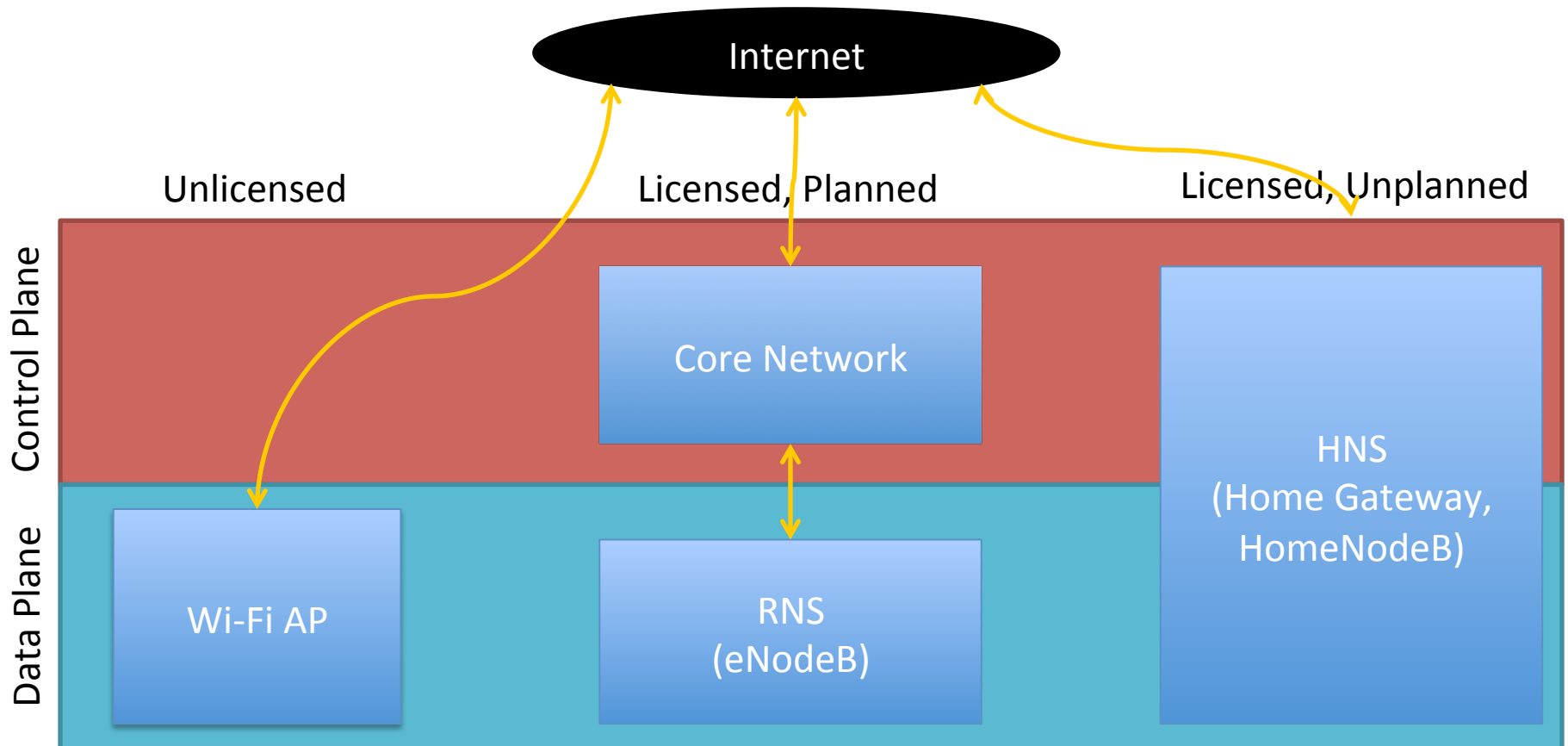
Crowd-sensing
Byte-counting



Crowd controller

Case 2: HetNets Control

(in collaboration with Intel Labs & Standardization)



Clients can autonomously manage/control their own configurations

Fog-Cloud Interface



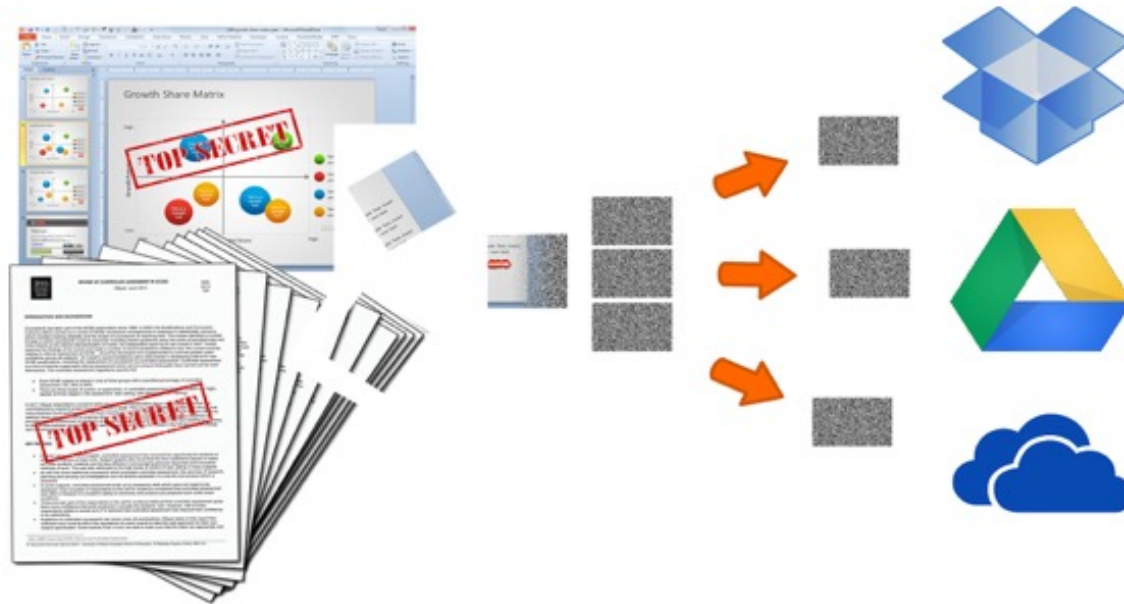
Real-time HetNets
selection



Long-timescale
parameter

Case 3: Shred and Spread

(in beta rollout in enterprise market)



Privacy control on Fog. Affordable storage at scale in Cloud.

Fog-Cloud Interface



Meta-data privacy control



Affordable storage
at scale

More Examples

(control plane & data plane)

- Over The Top (OTT) content management and SDP
- Client-centric HetNets Control
- Client-controlled cloud storage
- Session management and signaling load optimization
- Crowd-sensing inference of network states
- Edge analytics and real-time stream-mining

- Clients' idle computing/storage/content pooling
- Edge caching/BW management at home gateway/small cell
- FlashLinQ/LTE Direct/WiFi Direct/AirDrop
- Cloudlets/Micro Datacenters/Mobile CDN
- Client-driven distributed beam-forming

Fog – Cloud Interface



Brick

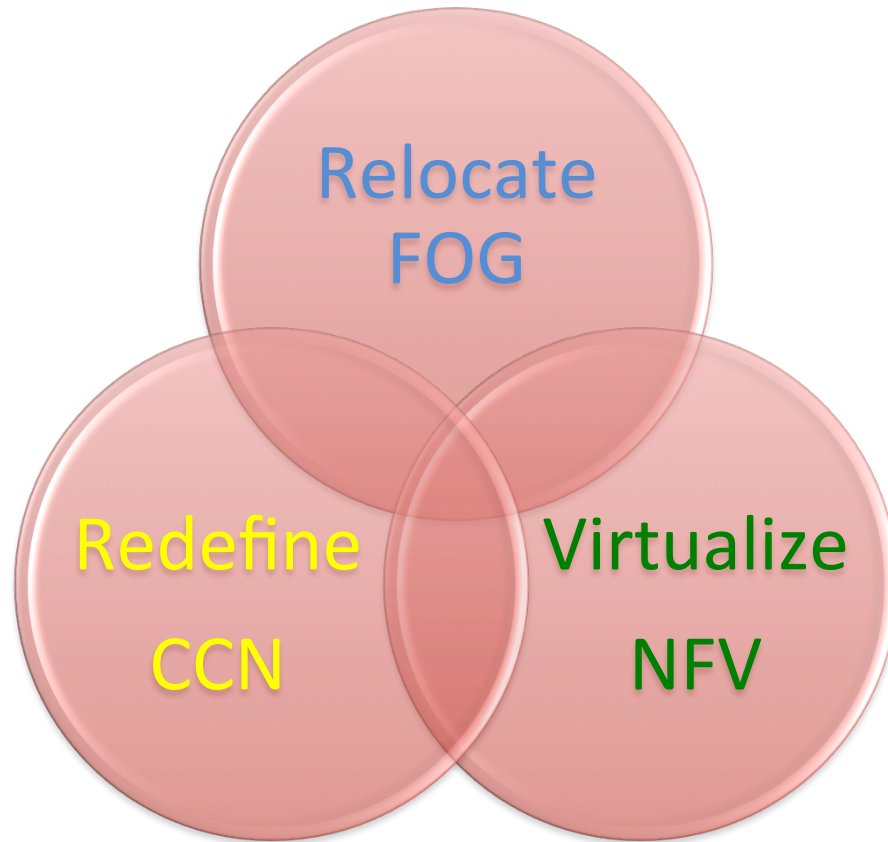
- Real time processing
- Rapid innovation
- Client-centric
- Edge resource pooling



Click

- Massive storage
- Heavy duty computation
- Global coordination
- Wide-area connectivity

Network Function Optimization



What is New?



MANET/sensor networks

Peer-to-peer content distribution

Edge networks

Much more interesting devices
Many more application scenarios
Network function optimization

Research Challenges

- **Tradeoff** of Local vs. Global, Distributed vs. Centralized
 - Coordination & consistency
 - Robustness through redundancy
 - Computational decomposition over heterogeneity
 - Successive refinement for stream mining
 - Task placement & scheduling along C2T continuum

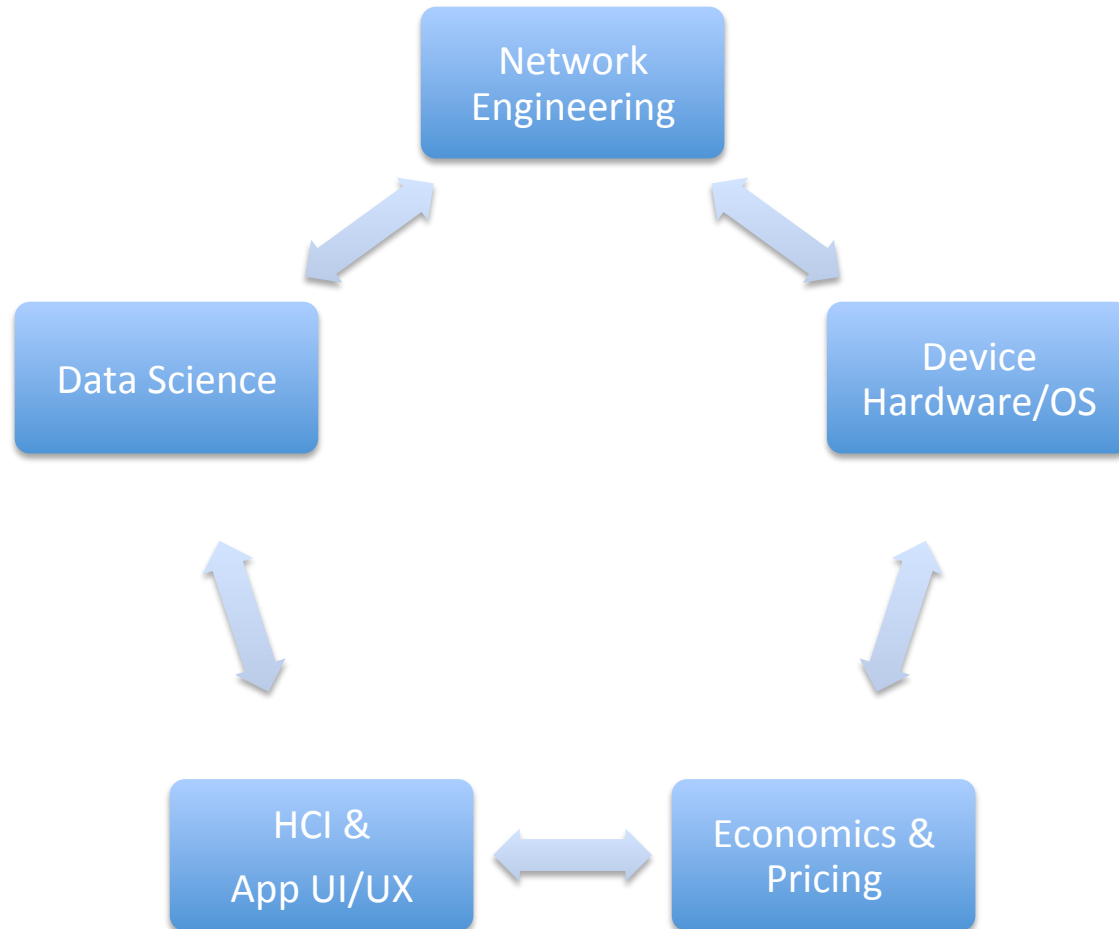
Research Challenges

- Interactions with OS
- Definition of network service APIs
- Interfaces: Fog-Cloud

Research Challenges

- **Trustworthiness/security** of client/access/
edge software & hardware
- **Incentivization** of fog node participation

Inter-Disciplinary Solutions



Join Us At

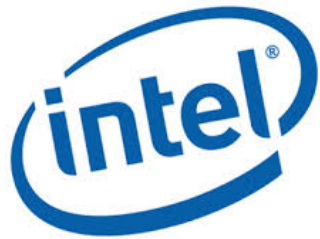
- Workshops/Panels
- Conferences
- Special issue ([IEEE Comm. Magazine: Sept. 1](#))
- RFI/RFP
- MOOC
- Book

<http://fogresearch.org>

Impact on Value Proposition along Ecosystem's Food-chain

- End user experience providers?
- Network operators?
- Equipment vendors?
- Cloud service providers?
- System integrators?
- Edge device manufacturers?
- Client/IoT device manufacturers/OS?
- Chip suppliers?

Industry-Academia Consortium



Thank You

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