ICN based Architecture for IoT-Requirements and Challenges (updated portion only)

(*draft-zhang-iot-icn-challenges-00.txt)*

IETF-91
IRTF/ICNRG, Honolulu

G.Q.Wang and Ravi Ravindran
(Huawei, USA)

ICN-IoT Draft Updates

- The draft was split to encourage participation:

draft-zhang-icn-iot-architecture-00.txt

draft-zhang-icn-iot-challenges-00.txt

Main Sections:
- IoT Application **Scenarios and Challenges.**
- IoT **Requirements**
- **State of Art**
- ICN **Challenges** for IoT

draft-zhang-icn-iot-architecture-00.txt

Main Sections:
- ICN-IoT as **Unified Platform**
- ICN-IoT **Architecture**
- ICN-IoT **Service Middleware**
- ICN-IoT **Deployment**

Contributors

- WinLab @ Rutgers U
  - Prof. Yanyong Zhang, Prof. Dipankar Raychadhuri
- Politecnico Di Bari
  - Prof. Alfredo L. Grieco
- INRIA
  - Prof. Emmanuel Baccelli
- UCLA
  - Prof. Jeff Burke
- Huawei
  - Ravi Ravindran & G.Q.Wang

Table of Contents

Table of Contents

Table of Content

Modified Section since ICN-RG meeting in Paris

Section- 5 : ICN Challenges for IoT

[Changes to this Section]

- Section aims at Scenario specific ICN-IoT challenges.
- Generally all the IoT requirements listed are met by ICN.
- But IoT requires special considerations considering different **scenarios with context**, such as
  - Heterogeneity of devices,
  - Interfaces,
  - Constrained factors,
  - Data processing,
  - Content distribution models,
  - Self organization

Naming and Name Resolution : requirement

- Naming
  - Scalability due to large number of entities
  - Trust in name assignment/Chain-of-trust
  - Deployability and Inter-operability: Between IP and ICN-IoT platforms, and also between various ICN-IoT realms based on different architectures.
  - Constructible Names Versus On-demand Publishing
- Name Resolution
  - Scalability and mobility
  - Latency : for real-time, delay-sensitive M2M applications
  - Locality and Network efficiency : faster local resolution, actuation due to ICN-IoT feedback systems for smart grids, industrial plants etc.
  - Agility : particularly in dynamic environments like VANET
  - Control/Scoping : Particularly to address Privacy, e.g. health monitoring

Naming and Name Resolution: scenario specific challenges

- Smart Homes
  - Names to enable local/wide-area networking
  - Security/Privacy/Access control
- Smart Grids
  - Consideration include to allow network control loops, real-time control, and security
- Smart Transportation
  - Handle extreme mobility, short latency, and security
- Smart Campus
  - Efficient naming for resource/service ownership and inter-connection among various heterogeneous sub-systems.

Caching and Storage: requirement

- Where to cache : Caching in constrained versus unconstrained part of the network. Latter is an open problem.
- What to cache : considering Streams of data. Caching Pub/Sub information in intermediate routers.
- Caching in the context of actuation, little meaning for authenticated requests, e.g. BMS

Caching and Storage:
scenario specific challenges

- Smart homes could use caching in gateway to access content.
- Smart Grids usage of caching to backup valuable data
- Transportation systems may implement in-network caching on vehicles for efficient information dissemination
- Smart Campus for social interaction and efficient content access.

Routing and Forwarding: requirement

- Can be classified into two categories
  - Direct and Indirect name-based routing
- Direct Name-based Routing
  - More challenging with flat names have be handled
  - Hierarchy gives natural aggregation
  - Challenges with producer mobility
- Indirect Routing
  - Uses a name resolution system to derive locators
  - Static Binding versus Dynamic Binding, later requires router to handle name-based routing

Routing and Forwarding:
scenario specific challenges

- Smart Homes : Need support for intra-domain and inter-domain routing protocols, e.g. service reachability within or access from outside too.
- Smart Grids: Robustness and Resiliency, and timely delivery or data.
- Smart Transportation: Satisfy V2V Ad hoc communication requirements
- Smart Healthcare: Timely and dependable routing and forwarding
- Smart Campus: Inter-domain routing protocols with minimal latency.

Contextual Communication: requirement

- Intelligence information gathering for Self-Configurability
- Contexts that can be processed in the network layer
- Approaches to handle context: Naming enhancement to signal context, and retrieve content objects
- ICN-IoT Middleware to process information
- Trust related challenges
- Real-time context processing
- Challenges as the Contexts and Devices grow

Contextual Communication: scenario specific challenges

- Smart Home : Many contexts depending on application such as temperature, location, time, number of occupants etc.
- Smart Grid : depends on specific segment of the grid being considered, e.g. location, time, voltage fluctuations etc.
- Smart Transportation: Many contexts which ware highly dynamic, location, time, # of vehicles, speed etc.
- Smart Healthcare : Context can be used to enhanced care, particularly during emergency situations.
- Smart Campus: Many systems inputs different contexts, hence have to be dealt differently.

In-Network Computing: requirement

- Host heterogeneous Services for network and service specific tasks.
- Meet security requirements, e.g. access control
- Context support requires in-network computing
- Process context reasoning
- Filtering noisy data, particularly for streaming data from sensors.

In-Network Computing : scenario specific challenges

- Smart Homes: Hosted on home gateways to resolve contexts
- Smart Grids : Increase the scalability and efficiency of the system
- Smart Transportation: to enable reliable and efficient communication between vehicle and infrastructure services
- Smart Healthcare: Resolve contexts, security, and improve dependability
- Smart Campus : Process Contexts from different applications.

Security and Privacy

Security and Privacy Challenges:

- Crucial to all IoT applications
- Challenges span confidentiality, integrity, authentication and non-repudiation, and availability
  - Security related processing considerations for constrained devices with very low processing and memory footprint.
  - Infrastructure – Naming by trusted entities, Protection of resources from adversaries, Man in the middle attacks involving message tampering, e..g sensor data resulting in performance degradation of network services.
- Considerations towards network functions like Naming/Name Resolution/Caching/Routing

Scenario Specific Challenges

- Most concern about Privacy, other than ensuring entities producing and consuming information are authenticated and trust worthy.

Energy Efficiency: requirement

- Fundamentally determined by the previously discussed components.
- Trade-offs have to be analyzed specifically for each scenario based on their objectives such as performance requirements, reliability, availability etc.

Comments and Suggestion

- Draft contributions from members are welcome.

Back UP

Section 1: ICN-IoT Motivation

- **Device Heterogeneity**
  - Things connection to the Internet
    - Personal, Industrial, Vehicles, Sensors etc
  - Potentially 50-100B Networked Objects
- **Connectivity Heterogeneity**
  - Wifi/802.15.4/BT/4G/5G
- **Service Heterogeneity**
  - Devices of all kinds offering different services
  - Hierarchical Service Realization – Collection/Aggregation/Processing/Distribution
- **Unified Platform**
  - Need for a Unified Platform to allow interaction at all levels
  - Device/Service/Control/Management Plane level
- **ICN can be a future Unified Platform**

Section -2: IoT Architectural Requirements

- **Naming**
  - Requirement driven due to Application requirements ,Secure/non-Secure, Persistance considering context changes such as Mobility or Scope
- **Scalability**
  - Due to Naming, Security, Name Resolution, Routing/forwarding aspects of the system design
  - Scale to billions on devices (passive/active), name/locator split, local/global services, resolution infrastructure, efficient context update.
- **Resource Constraints**
  - Resource constrained and sufficient devices
  - Power/Compute/Storage/Bandwidth constrains and how it affects resource constrained device operations.
  - User interface constraints with the users.
- **Traffic Characteristics**
  - Separate Local versus Wide Area traffic based on Application logic ; Many-to-Many (Multicasting/Anycasting)
  - Requirement for efficient means for data aggregation service discovery, resolution, and association. Optimize for bandwidth/enery consumption for uplink/downlink communication. Provisioning requirment considering Traffic shaping needs.

IoT Architectural Requirements

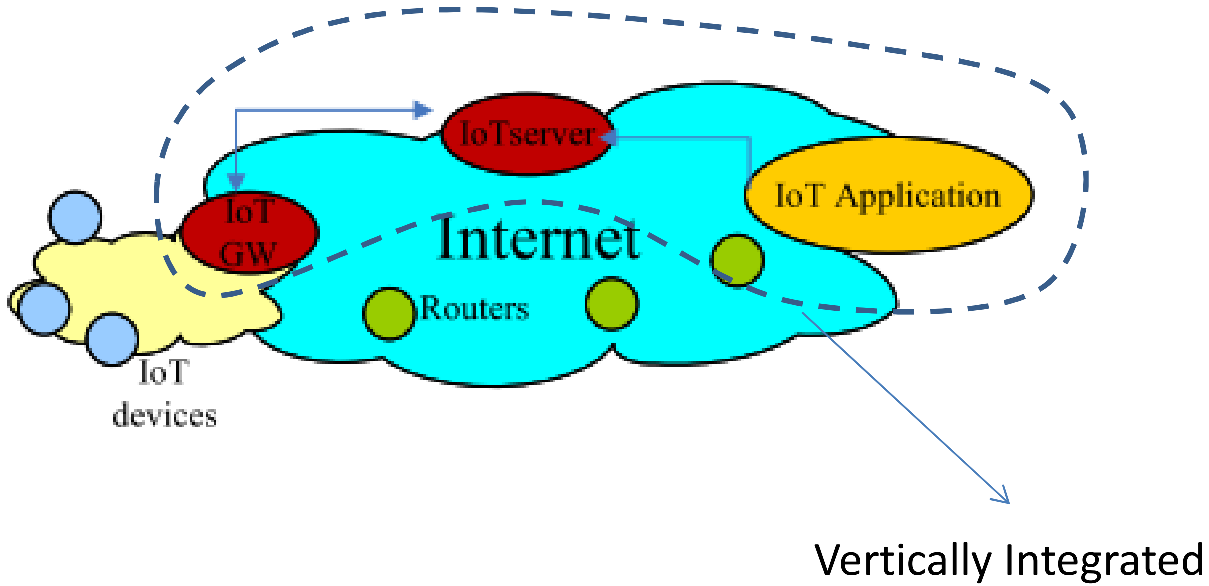
- **Contextual Communication**
  - Requirements to support Contextual interaction based on location, physical proximity among devices, time, cross-contextual considerations.
  - Driven due to Short and Long term Contextual needs of applications .
- **Handling Mobility**
  - Movement of Static Assets versus very dynamic V2V environments
  - Requirements due to Data Producer/Consumer/IoT Network mobility; Disconnection between data source and destination pair (unreliable wireless link). Meet application requirements.
- **Storage and Caching**
  - Linked to privacy and security of requirements of IoT applications.
  - Pervasive versus Policy driven requirements for storage and caching
  - Requirement on efficient resolution of cached content while adhering to policy requirements
- **Security and Privacy**
  - Trust Management, Authentication, Access Control at different layers of the IoT system
  - Privacy related to both Content and Context of its generation.

IoT Architectural Requirements

- Communication Reliability
  - Requirement considering mission critical, and non-mission critical applications
  - Implication on QoS, Routing, Context, and System Redundancy (device, storage, network etc.)
- Self Organization
  - Able to self organize – discovery or heterogenous and relevant devices/data/services based on context.
  - Scalable Platform to support pub-sub services while supporting mobility, in-network caching, name-based routing.
  - Private Grouping/Clustering based on privacy and security requirements.
- Adhoc and Infrastructure Mode
  - Devices could operate in either of these modes
  - Energy efficient topology discovery and data forwarding in adhoc mode and scalable name resolution in infrastructure mode.
- Open-API
  - To foster large scale inter-operability in terms of Push/Pull/Pub-Sub operation between consumers, producers, and IoT services.

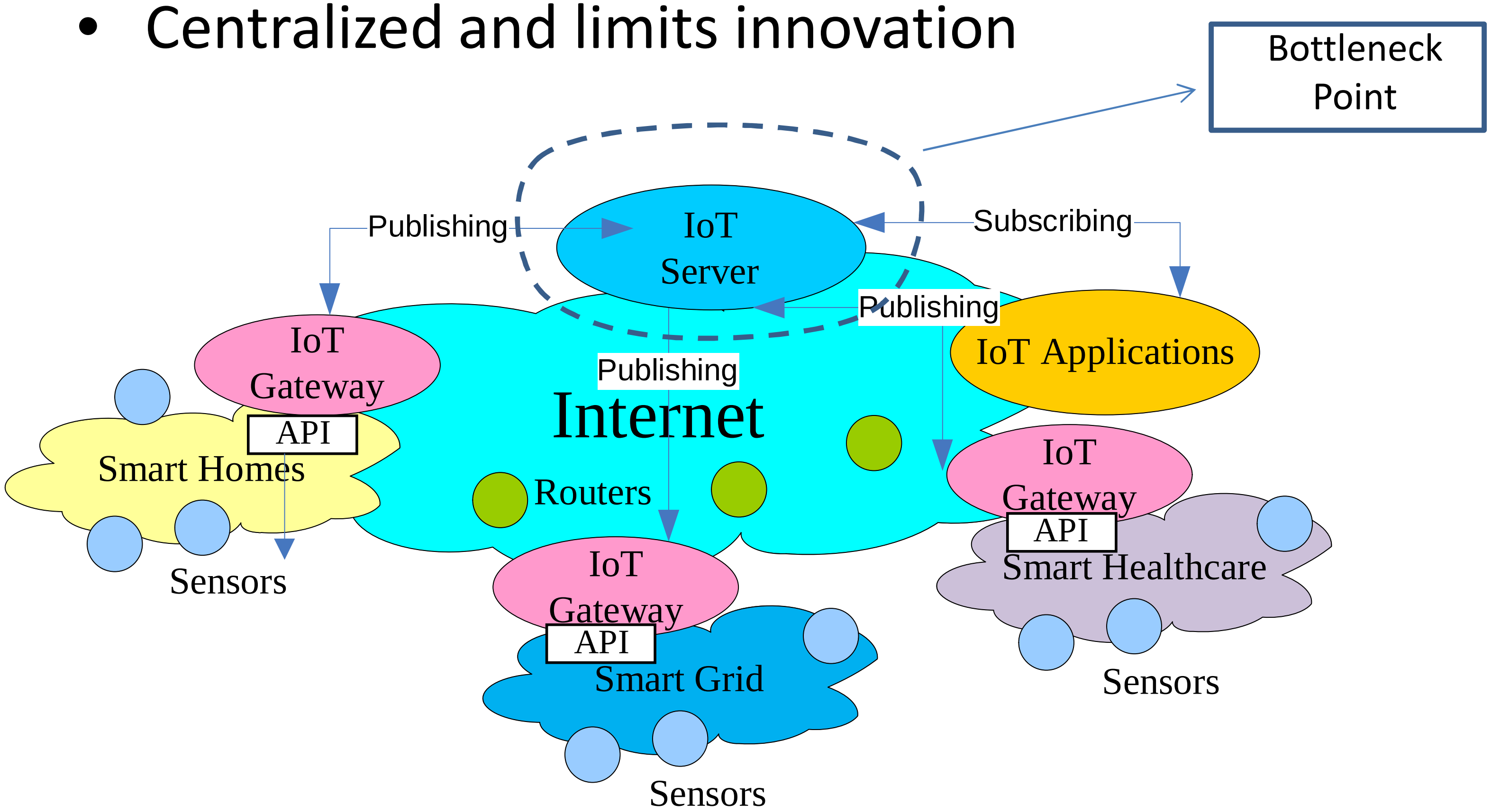
Section-3: Legacy IoT systems

- Silo IoT Architecture: (Fragmented, Proprietary), e.g. DF-1, MelsecNet, Honeywell SDS, BACnet, etc.
- A small set of pre-designated applications.
- Moving towards Internet based service connectivity (ETSI, One M2M Standards).



Section-3: State of the Art

- Internet Overlay Based Unified IoT Solutions, inter-connecting multiple publishers and consumers
- Coupled control/data functions
- Centralized and limits innovation



Section 3- Weakness of the Overlay Approach

- System not designed in a holistic manner to inter-connect heterogeneous devices, services, and infrastructure.
- Relies on IP for transport which has inherent weakness towards supporting a unified system.
- Cannot satisfy many requirements:
  - Naming : Resources coupled with IP address
  - Security : Channel based security model, inflexible trust models
  - Scalability – Using IP addresses as identifiers; affect on routing table size. Lack of unified application level addressing and forwarding.
  - Resource Constraints : Push versus Pull
  - Traffic characteristics – point to point, requriement for multicast
  - Contextual Communication, as all the information is at the server
  - Mobility – Session based
  - Storage and Caching
  - Self Organization
  - Ad hoc and Infrastructure mode

Popular Scenarios

- For each of the these scenarios, we discuss the general and IP based overlay challenges.
- **Home Challenges**
  - Topology independent service discovery
  - Common protocol for heterogenous device/application/service interaction
  - Policy based routing/forwarding
  - Service Mobility as well as Privacy Protection
  - Inter-operate with devices with Heterogenous naming, communication and Trust models
  - Ease of use
  - Foreign Devices

Section -4: Popular Scenarios

- **Enterprise**
  - Campuses, industrial facilities, retail complexes
  - Complex environments which integrate business and IT systems
  - H2M, M2M interaction
  - Efficient secure device/data/resource discovery
  - Inter-operability between different control systems
  - Reliable communication

Section-4: Popular Scenarios

- **Smart Grid**
  - Data flow and information management achieved by using sensors, actuators enabling substation and distribution automation
  - Chalenges include reliability, real-time control, secure communication, and data privacy
  - Scale to large number of heterogenous devices
  - Real time data collection, processing, and control
  - Resiliency to failures
  - Critical infrastructure hance security in terms of malicious attacks, intrusion detection and route around failures

Section-4: Popular Scenarios

Transportation

- Increasing sensors in vehicles in general
- Networking in-vehicle network/applications with external network/services for safety, traffic conditions, entertainment etc
- Challenges span : Fast data/device service discovery and association, efficient communication with mobility, trustworthy data collection and exchange, inter-operability with heterogenous devices, security..

Section 4- Popular Scenarios

- Healthcare
  - Realtime interaction
  - High reliability and strict latency requirments
  - Trust, Security, Privacy and Regulations
  - Heteorgenous devices and Inter-operability
- Education
  - How IoT systems can enhance learning about environments with increasing instrumentation of environments
  - Simplying communication between devices, applications and services, moving away from host oriented approaches
  - Security
  - Real-time communication
  - Heterogenous devices, manufacturers, and siloed approach limits innovation
- Entertainment Arts and Culture
  - Integrating multiple smart systems to create new experiences
  - Time synchronization
  - Simplicity for experimentation and development
  - Security

Thank You