RIOT, Internet of Things and ICN

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IoT, ICN, RIOT

• Internet of Things
• Information Centric Networking
• RIOT
Internet of Things

• Connect sensors, actuators, devices, systems with analytics, management and control
• Interconnect systems that formerly operated independently
• Use open, standards-based protocols and infrastructure to maximize opportunities for innovation
Power Management

Smart Grid

- Power Generation
- Transmission (Utility)
- Distribution (Local Utility)
- Federated Data Centers
- Distributed Generation Sources
- Network (Local Utility)
- Network Control Center
- Industrial Customer
- Commercial Customer
- Residential Customer

Energy ➔ Information

“Things” at the edge

- Sensors, actuators, other devices
- These devices often have quite limited resources
  - Energy
  - Memory
  - CPU
  - Network
- Challenge: Provide quality connectivity with these limited resources
Communication Protocols and the Internet

• Communication protocols define how devices interact over a telecommunication network
• From the Greek protokollon, a description of the contents of a manuscript
• These protocols are based on a series of design principles, guidelines and decisions that shape the way devices communicate and across the Internet
• Information Centric Networking (ICN) is a radical rethinking of the network communications paradigm, based on many different design guidelines and decisions
TCP/IP Protocol Suite

- Communication is between processes-hosts, identified by addresses
- End-to-end principle – network forwards with no state per message
- Reliable delivery
- Congestion control
- Address is fixed-length number combining identification and location
- Multicast – best effort with several styles of implementation
- Mobility – change in location implies change in address
Sending Data with TCP/IP

Sending process

TCP

IP

Router

Receiving process

TCP

IP

Router

Sending computer

Receiving computer
Information Centric Networking: ICN

- Networking technology that starts from a clean slate; shares “packet forwarding” with IP and not much else
- Based on the observation that Internet traffic today is largely requesting data; think of requesting web pages
  - Consumer generates a request for some named data, called an Interest
  - Interest is forwarded to a place (or places) in the network where the corresponding named data exists; each forwarder records the interface on which the Interest was received
  - Data is returned in a Content message. Following back pointers
- Data in Content is crypto-signed to prove validity
- Contents can be pre-stored at multiple locations in the network
- Contents can be cached by forwarders for later use
Characteristics of ICN

- Communication is between consumers and named data
- Forwarders interact with messages and maintain per-message state
- Names for data (no addresses for devices)
- Novel forwarding strategies
- Ad-hoc multicast through content storage in forwarders
- Consumer mobility is easy
- Open questions…
  - Push model communication in a pull model world
  - Routing
  - Congestion control
  - ...and many more
ICN Example

Consumer

Interest

ICN

Receiving computer

ICN Forwarder

ICN Forwarder

ICN Forwarder

Producing computer

Producer

ICN
ICN Example

- Consumer
  - ICN Forwarder
  - Interest
- Receiving computer
- Producing computer
- Producer
  - ICN Forwarder

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ICN Example

Consumer

ICN Forwarder

ICN Forwarder

ICN Forwarder

Receiving computer

Interest

Producer

ICN Forwarder

ICN Forwarder

ICN Forwarder

Producing computer
ICN Example

Consumer

ICN

Receiving computer

ICN Forwarder

ICN Forwarder

ICN Forwarder

Producing computer

Producer

ICN

Interest
ICN Example

Receiving computer

ICN Forwarder
ICN Forwarder
ICN Forwarder

Producing computer

ICN

Consumer

Producer

Interest
ICN Example

Consumer

ICN

ICN Forwarder

ICN Forwarder

ICN Forwarder

Receiving computer

Producing computer

Producer

ICN

Content

ICN Forwarder

ICN Forwarder

ICN Forwarder

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ICN Example

ICN Forwarder

Receiving computer

Content

ICN Forwarder

ICN Forwarder

Producing computer

Content
ICN Example

Consumer

ICN

Receiving computer

ICN Forwarder

Content

ICN Forwarder

Content

ICN Forwarder

Content

Producing computer

Producer

ICN
ICN Example

Receiving computer

Producer

Content

ICN Forwarder

ICN Forwarder

ICN Forwarder

ICN

ICN

Content

Content

Content

Producing computer

Receiving computer

ICN Forwarder

ICN Forwarder

ICN Forwarder

ICN

ICN

Content

Content

Content
ICN Example

- Consumer
  - Content
  - ICN
  - Receiving computer

- Producer
  - Content
  - ICN
  - Producing computer

- ICN Forwarder
  - Content
  - Content
  - Content
Why ICN for Constrained Networks?

- Simplicity – implementation, operation
  - Mobility/dynamic topology
  - Novel forwarding strategies
  - Address management
  - Routing
  - Security
Node-Gateway Data
Node-Gateway Data
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Gateway-Node Communication (Asynchronous)
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Dynamic Network Topology
Dynamic Network Topology
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Dynamic Network Topology
Dynamic Network Topology

Gateway
Dynamic Network Topology
Cisco ICN Forwarder

FIB: Forwarding Information Base
PIT: Pending Interest Table
CS: Content Store
Face: Point-to-point association with another node

Background process:
• Beaconing
• Neighbor enumeration
• Link assessment
• Face management
Cisco ICN Forwarder

Interest:
- Forwarder process receives Interest from RIOT driver
- Add PIT entry with Face ID
- If Content is in CS, return Content
- Look up Interest in FIB and forward to next hop

Content:
- Forwarder process receives Content from RIOT driver
- Add Content to CS
- Look up Content in PIT
- Forward to next hop, delete FIB entry
Cisco ICN Application

Consumer:
- App builds interest and send to Forwarder through Face
- Forwarder adds PIT pointing to App face
- Forwarder

Producer:
- PIT entry points to inbound Face
- Interest delivered to App through Face
- App generates Content, returns through Face
- Forwarder looks up PIT entry and forwards Content
CICN Forwarder Implementation

Forwarder Thread

Beacon Timer
Beacon Thread
RIOT-OS Radio interface

FACE
FIB
PIT
CS
FACE
FACE

ICN Forwarder

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Cisco ICN Forwarder Development

- Build the forwarder in the os-riot examples directory
- Makefile includes “USEMODULE += cicnlib”
- git updates require almost no manual intervention
- Targets: OpenMote, SAMR21-XPRO, (Cisco) Trifecta, Native
Securely Joining an ICN Network

- Joining a wireless mesh network is first step in ZigBee-IP, WiSUN FAN
  - Authenticate and authorize joining node
  - Authenticate and authorize joined network
- How can secure join be implemented in ICN?
  - Assume authentication agent in gateway
  - Assume PSK between joining node and gateway
  - Neighbor node authenticates joining node and delivers network authentication to joining node
Comparison: ICN and ZigBee-IP

- Bytes over-the-air: 80% reduction
- Crypto operations: 10% increase
- Energy consumption: 50% decrease

*Full paper to appear in ACM ICN 2016*
A Software Platform for IoT

• Open source platform for constrained device development is key – think of ”Linux for IoT”
  • Requirements: good technology base, community dev process, support, wide base of supported platforms
  • Linux-based unsuitable
  • Examples: RIOT, Contiki, XINU
ICN and RIOT: a good match…

- Appropriate APIs: Network level interface
- Adaptable: easy to leave off entire IPv6 stack
- Application build support: integrated ICN libraries and application into existing RIOT build and update infrastructure
- Resulting forwarder/application fits comfortably in typical constrained device