L3 Routing and Mobility Support in Emerging Wireless Mesh/Sensor Networks

Myung-Ki SHIN

mkshin@etri.re.kr

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   - Wireless Mesh Network (WMN)
   - Wireless Sensor Network (WSN, USN)
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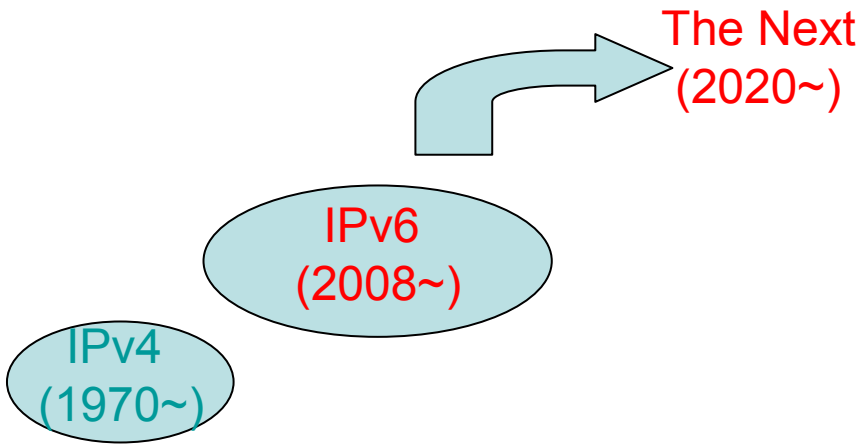
Internet for the Future

- **Historical Timeline**
  - Packet switching invented (1962)
  - Internet concept invented (1974)
  - IP designed (~1978)
  - BGP designed (~1988)
  - CIDR designed (1992)
  - IPv6 designed (1995)
  - What's the next ? (~2020)
- ***Growing concern about scaling, transparency, multihoming, renumbering, traffic engineering, IPv6 impact (1995-2006), etc.***
- **Two Approaches**
  - Evolutionary Approach (e.g., IETF)
  - Revolutionary Approach (e.g., "*Clean Slate Approach*")

Requirements for the Future

❑ Requirements & Goals

- **Scalability**
- **Ubiquity**
- **Mobility**
- Security/Robustness
- Re-configurability
- Context-awareness
- Manageability
- Heterogeneous

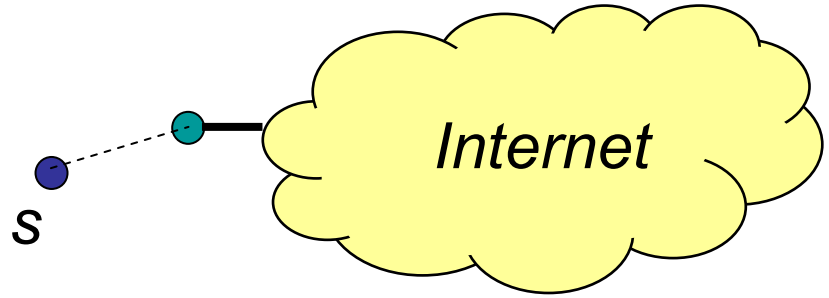


❑ Emerging Future Stub Networks

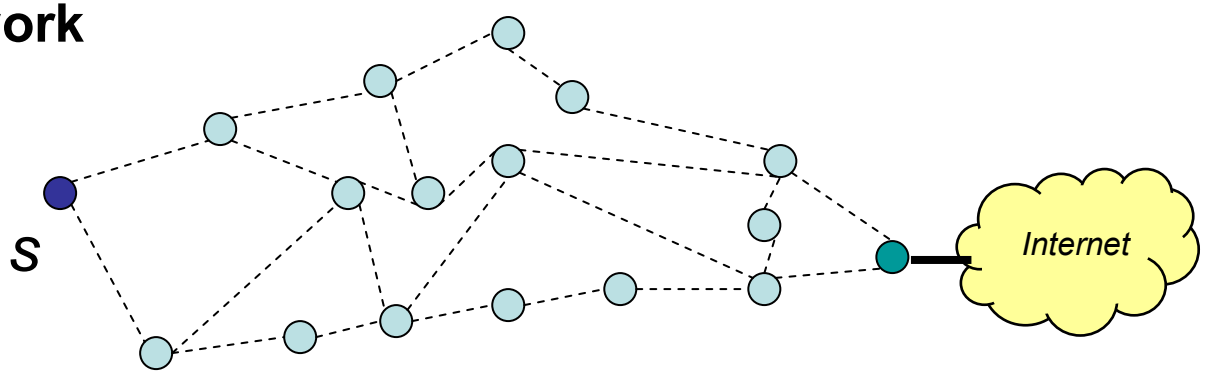
- **Wireless Mesh Networks (WMN)**
- **Sensor Networks (WSN vs. USN)**

Evolution to Future Networks

- **Huge Wired Core + Wireless Access (one hop)**

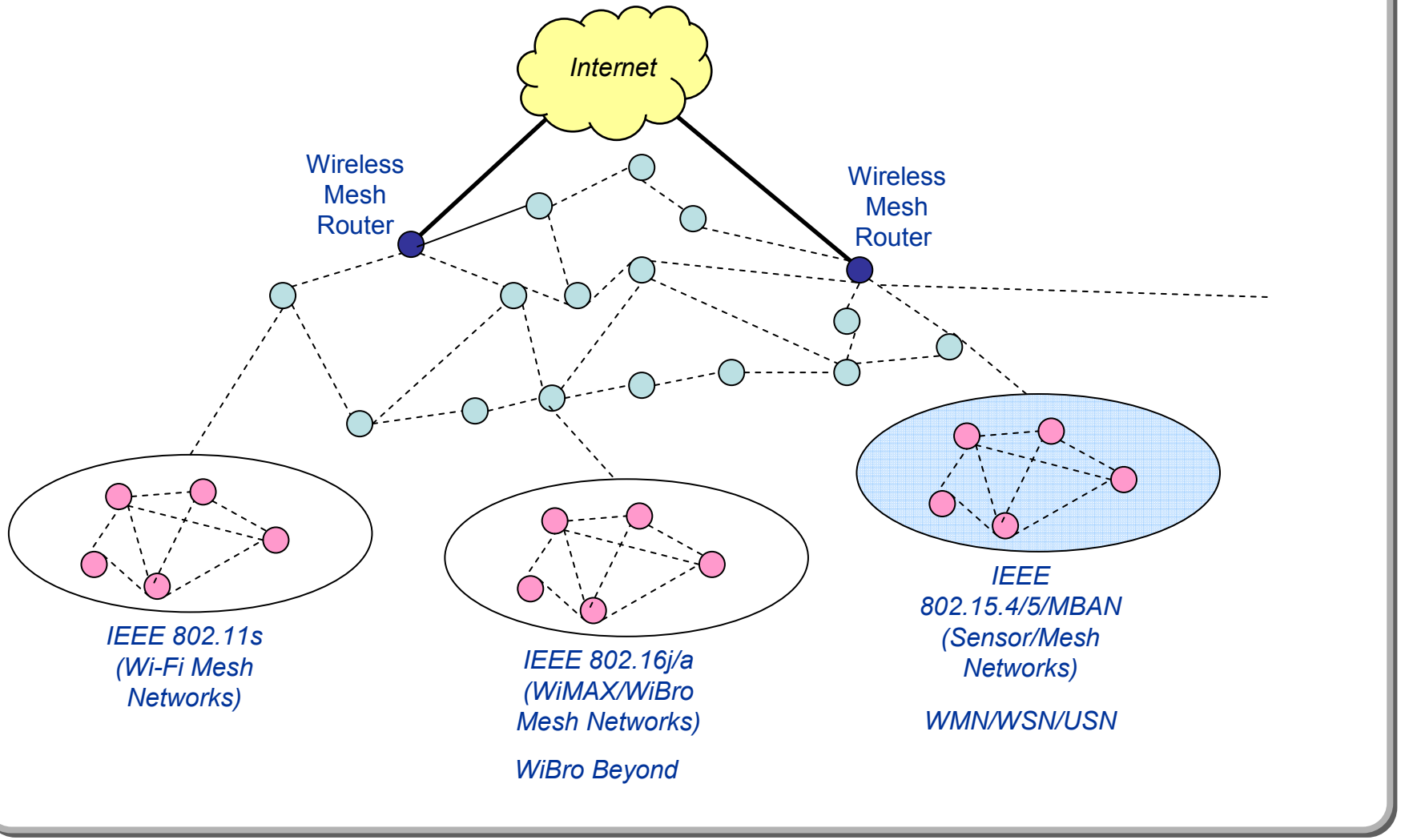


- **Wireless Mesh/Sensor Networks (multi hops) + Small Wired Network**



Wireless is the Key driver for the Future Network …
=> sensor network, DTN, Ad-hoc/mesh, pervasive computing ….

Future Networks - Example



Routing for Sensor Networks

❑ Why L3 Routing for Sensor Network ?

- Sensor and many other radio networks will be made using various L1/L2 protocols defined by many SDOs:
  - 802.15.4, WiFi, WiBro(Mobile WiMAX), non wireless links …
- Such networks will also comprise sensor nodes with a wide range of capabilities
  - **which makes the routing fairly unique in term of requirement**.
- Routing for sensor networks is different than other networks because they operate under different constraints.
  - 1) Nodes are energy-limited
  - 2) One repercussion of 1) is that nodes are state-limited

L3 Routing Issues

- **Two Approaches in IETF**
  - RSN/R2LN: "Routing Issues for Low Power Wireless Networks "
    - draft-culler-rsn-routing-reqs-00
      - define the routing requirements for Sensor Networks above the IP
  - Routing in 6LoWPAN
    - draft-dokaspar-6lowpan-routreq-01
      - support for mesh routing under the IP ("*mesh-under*")
- **Common Assumptions**
  - Not be a single routing protocol satisfying the entire list of requirements, in which case it may be decided to define a limited set of routing protocols

RSN/R2LN - Goals

- **L2 Technology Agnostic Routing**
  - Awareness of beacon capabilities seems to be a drastic move.
- **Describe a L2 Service API**
  - Sufficiently precise abstraction of the L2 so that the L3 (routing layer) can make sensible decisions
- **Capabilities Provided by the Lower Layer (E.g.)**
  - Guaranteed delivery to another node (Yes/No)
  - Worst-case time for delivery of a packet to another node (may depend on target node capabilities)
  - Power properties (AC / AC w. batt. Backup / Big battery / Button cell battery / Environmental -sun or wind)
  - Availability of another node (A sun-powered node may be available and reliable for long periods, but not always...)

(Source : RSN/R2LN mailing list)

RSN/R2LN - Reqs.

❑ Unique Routing Requirements of Sensor Networks

- Spatially-Driven Multi-hop
- Light Footprint
- Small MTU
- Deep power management
- Heterogeneous Capabilities
- Highly Variable Connectivity
- Structured Workload and Traffic Pattern
- Partial Information
- Quality of Service Capable Routing
- Data Aware routing

(Source : draft-culler-rsn-routing-reqs-00)

6LoWPAN Routing Reqs.

General Requirements:

- Layer Transparency, Gateways
- Robustness despite hibernating nodes
- Local and Global Mobility
- High Scalability
- Secured control messages
- Bootstrapping

Special to 6LoWPAN:

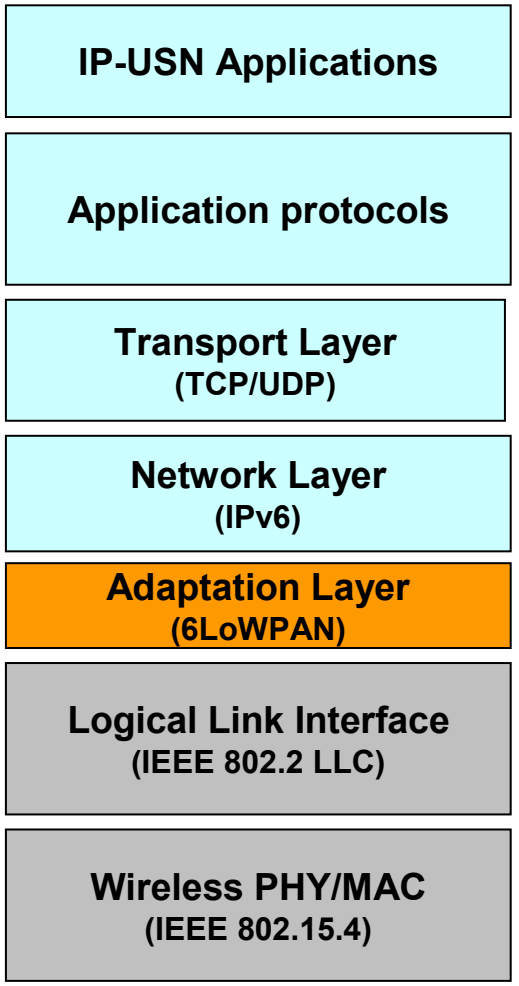
- Reusing MANET Protocols
- Adaptation Layer Routing
- No PHY frame fragmentation of control messages
- 16 bit and 64 bit Addressing
- Local repair MAY be omitted
- ND without “Hello” Messages (L2-mechanisms)
- Low Protocol Complexity
- Low Routing State
- Short code length

➔ Common requirements or guidelines for 6lowpan routing will lead to design refined routing solutions.

(Source : draft-dokaspar-6lowpan-routreq-01)

What's 6LoWPAN ?

- **One of good applications of Sensor Networks Deployment**
- **What's 6LoWPANs ?**
  - Low Cost, Low Power, Low Speed, Limited Distance
    - 900~2400MHz, 20~250kbit/s
    - FFD (Full-Function Device) vs. RFD (Reduced-Function Device)
  - Mesh network of interconnected devices
    - 10s to 1000s of nodes
  - Conforming to IEEE 802.15.4-2003 Standard



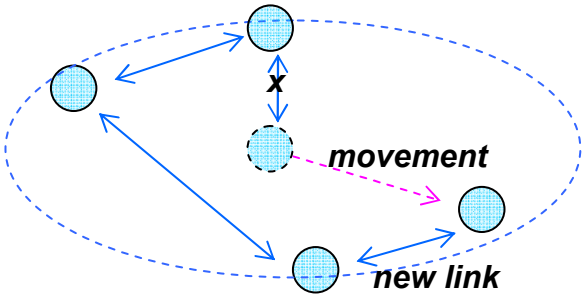
Mobility Support Issues

- **Sensor networks are likely to consist of nodes with a certain degree of mobility.**
  - While mobility is an issue in many sensor networks, many are quite stationary …
    - Requiring the stationary ones to incur the energy cost of the overhead of supporting mobility might not be a good idea
  - Due to the low performance characteristics of sensor nodes, mobility support should be provided without high signaling involvement in end devices (e.g., RFD).
  - Fast mobility detection will be a huge challenge and sensor nodes might even change their location while being in state of hibernation.

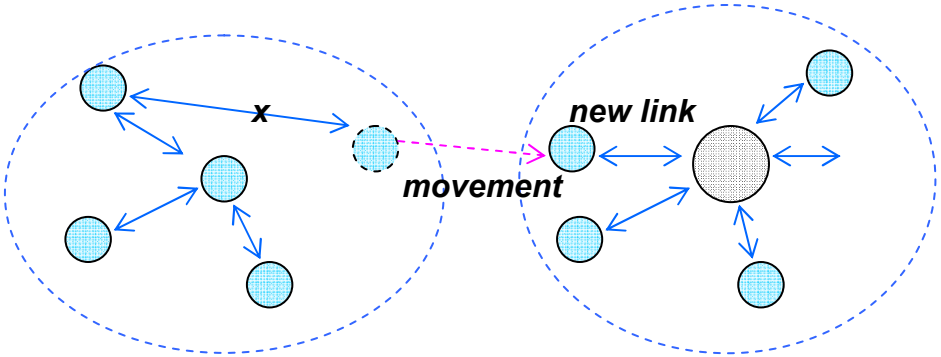
Mobility Support - Goals

- **It is crucial to reduce the additional mobility related signaling overhead or to possibly avoid it altogether.**
  - Especially to optimize power consumption, battery-powered devices should be correctly discovered and handled by more capable (and possibly mains-powered) devices in the network, such as the CFD.
- **The fundamental goals …**
  - Mobile sensor nodes must be addressable by any corresponding node, independent of the current whereabouts.
  - RFDs are not to be involved in any mobility related signaling.
  - Reduction of mobility signaling messages for FFDs.
  - Reuse of existing mobility protocols (?)

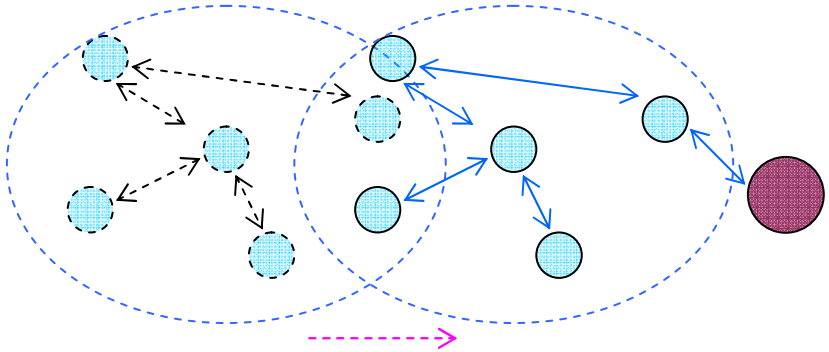
Mobility Scenarios



case – 1 (MANET)

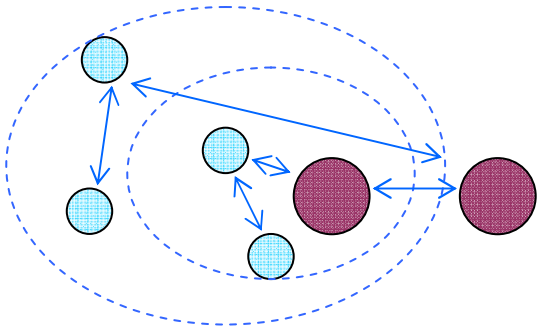


case – 2 (Movement b/w WPANs)



movement

case – 3 (NEMO)



case – 4 (MANEMO – Nested NEMO)

(Source : draft-shin-6lowpan-mobility-00)

Case 1 : MANET

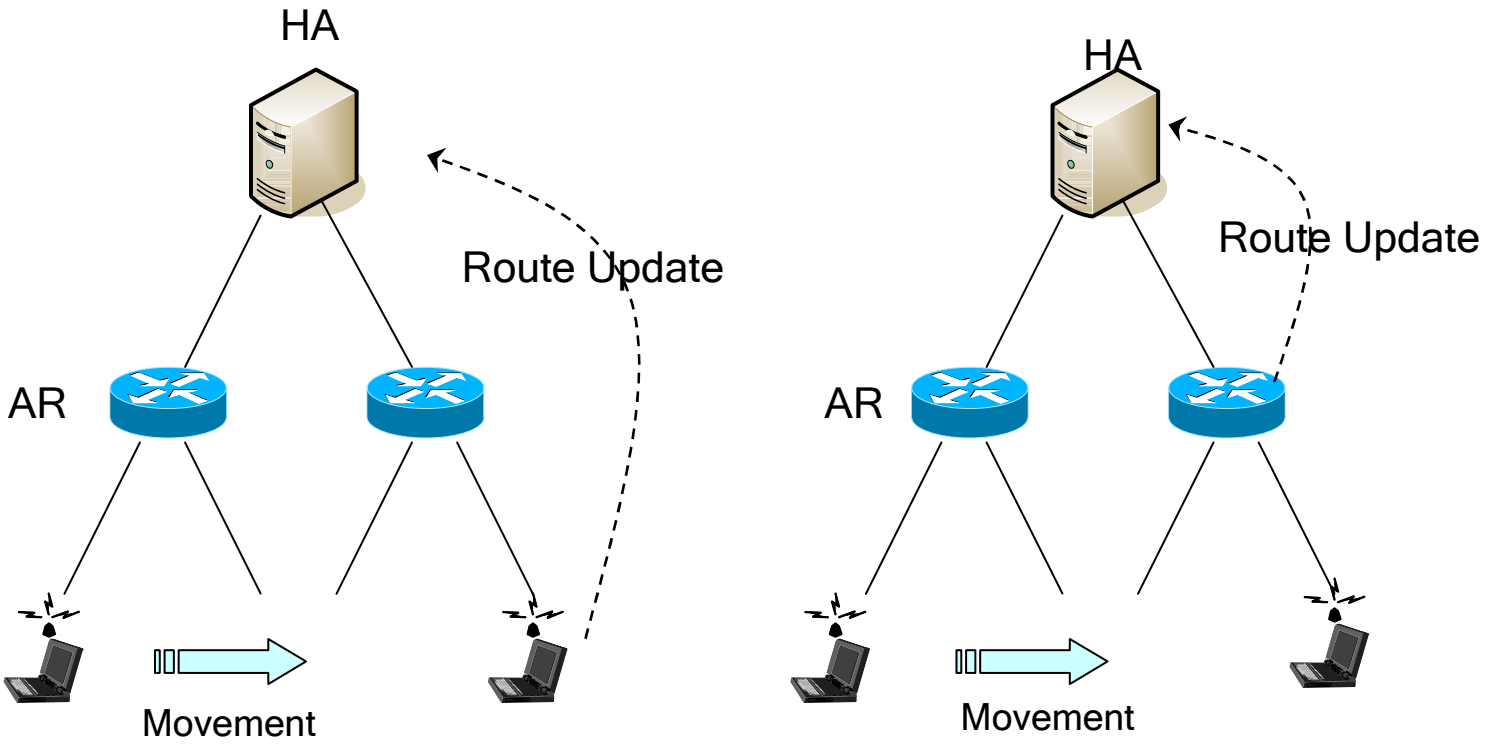
- **Wireless Ad-hoc Routing**
  - IP routing protocol functionality suitable for wireless routing application within dynamic topologies
- **IETF MANET Protocols**
  - Reactive MANET Protocol (RMP) - On-demand
    - RFC 3561: AODV – Ad-Hoc On-Demand Distance Vector Routing
    - Dynamic MANET On-demand (DYMO) Routing (I-D)
  - Proactive MANET Protocol (PMP) - Exchanges topology information
    - RFC 3626: OLSR – Optimized Link State Routing - <OLSRv2>
- **For Sensor Networks :**
  - No need to define mobility protocols additionally
  - Shares same goal, but for ultra-low performance devices (i.e. sensor nodes).
    - Simplification and Optimization Required

Case 2 : Movement b/w WPANs

- **Network-based Mobility Management Approach (e.g., Proxy MIPv6) would be preferred.**
  - PMIPv6 does not require any mobility protocols in sensor nodes.
  - Instead, gateway (CFD) performs mobility functions (e.g., Proxy BU).
- **For Sensor Networks :**
  - Current PIMv6 defines the device-to-gateway interface applied in a single-hop. However, multi-hop and mesh topologies should be additionally considered
    - e.g., ad-hoc routings or ND extensions can be added to support multi-hop device-to-gateway interface.

Network-based Mobility Support

❑ MIP vs. Proxy MIP



Case 3 : NEMO

❑ RFC 3963 - NEMO Basic Support Protocol

- NEMO support concerned with managing the mobility of an entire network, viewed as a single unit, which changes its point of attachment to the Internet and thus its reachability in the Internet topology.
- Such a network is referred to as a mobile network and includes one or more mobile routers (MRs) which connect it to the global Internet.

❑ For Sensor Networks :

- Mobility network == WPAN
- Mobile router == Sink node/CFDs

Case 4 : MANEMO

❑ MANET for NEMO

- MANEMO is a special case for Nested NEMO.
  - When mobile routers (CFDs) and mobile nodes (RFDs/FFDs) converge at the edge of the Internet using wireless interfaces, they can form a sensor network in an ad-hoc fashion and are able to provide Internet connectivity to one another.
- Several issues exist in this network configuration
  - E.g., network loop, un-optimized path and multiple exit routers to the Internet.

❑ For Sensor Networks :

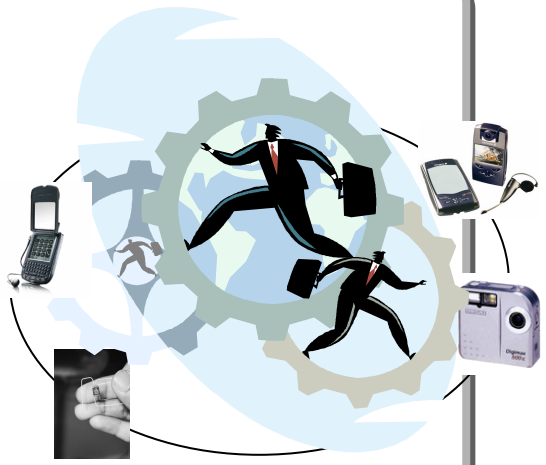
- While fixed routers provide constantly connectivity, mobile routers (CFDs) can experience intermittent connectivity to the Internet due to their movement.
- MANEMO solution is not finalized yet and it is at initial stage. If it is done, it can be adopted well without any modifications.

MANEMO - Applications

- 6LoWPAN Scenarios (L3 Mesh and Sensor Network)
- Fleet at sea
- Crowd of Personal Mobile Router
- Deployable and Mobile networks (e.g., Ships, vehicles, airborne)
- Disaster-Ready municipal network
- Various Access Points Discovery (beyond 802.21)

Discussion

- Mesh/Sensor networks will be one of emerging future stub networks for the Future Internet …
- Is L3 routing necessary for sensor networks ?
  - which makes the routing fairly unique in term of requirement.
- A lot of mobility scenarios and applications for sensor node/network



- We plan to submit this topic to ISO/IEC JTC1 SC6 Ad-hoc meeting – Future Networks …
- Also try to hold new WG in IETF/IRTF or new Question in ITU-T SG13?

References

- **RSN/R2LN:**
  - draft-culler-rsn-routing-reqs-00 (ArchRock & Cisco)
  - http://www1.ietf.org/mail-archive/web/rsn/current/index.html
- **Routing in 6LoWPAN:**
  - draft-dokaspar-6lowpan-routreq-01 (ETRI)
- **Mobility in Sensor Networks:**
  - draft-shin-6lowpan-mobility-00 (ETRI)
- **MANEMO:**
  - http://www.mobileip.jp/MANEMO/MANEMO.html (Keio Univ.)