IPv6 over Low power WPAN WG (6lowpan)

Chairs:

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- **We assume people have read the drafts**
- **Meetings serve to advance difficult issues by making good use of face-to-face communications**
- **Be aware of the IPR principles, according to RFC 3979**

✓Blue sheets
✓Scribe(s)

72nd IETF: 6lowpan WG Agenda

09:00	Introduction, Status	Chairs (20)
09:20	1 – Bootstrapping/ND optimization	(65)
10:25	2 – HC	(20)
10:45	3 – Architecture	(10)
10:55	4 – Routing Requirements	(10)
11:05	5 – Use cases	(10)
11:15	6 – Security	(10)
11:25	0 – unchartered	(15)

What is 6lowpan?

- **Interesting L2 network: IEEE 802.15.4**
  - **Low power, 20..250 kbit/s, 900 and 2400 MHz**
  - **Almost, but not entirely, unlike 802**
    - Small MTU, limited range
- **Job of 6lowpan: make this look like an IPv6 link**
  - **Classical encapsulation issues → format document**
  - **Reachability: mesh routing**
    - can do route-over, too
  - **No multicast: emulate, avoid (e.g., ND)**

Segment 1: WG Status
09:10–09:20

Chairs

Milestones (from WG charter page)

Document submissions to IESG:

- **Aug 2008 2 Improved Header Compression (PS)**
- **Aug 2008 6 Security Analysis (Info)**
- **Sep 2008 3 Architecture (Info)**
- **Sep 2008 4 Routing Requirements (Info)**
- **Nov 2008 1 Bootstrapping and ND Optimizations (PS)**
- **Dec 2008 5 Use Case (Info)**

Also: running documents for implementers, interop

Charter 1/6

1. Produce "**6LoWPAN Bootstrapping and 6LoWPAN IPv6 ND Optimizations**" to define limited extensions to IPv6 Neighbor Discovery [RFC4861] for use specifically in low-power networks. This document (or documents) will define how to bootstrap a 6LoWPAN network and explore ND optimizations such as reusing the structure of the 802.15.4 network (e.g., by using the coordinators), and reduce the need for multicast by having devices talk to coordinators (without creating a single point-of-failure, or changing the semantics of the IPv6 ND multicasts). **[PS]**

Charter 2/6

2. Produce "**6LoWPAN Improved Header Compression**" to describe mechanisms to allow enhancements to the 6LoWPAN headers. Specifically this document will describe compression of addresses that are not link-local. Additionally this document may include other enhancements or optimizations of the HC1 or HC2 6LoWPAN headers. This document will be a proposed standard. **[PS]**

Charter 3/6

3. Produce "**6LoWPAN Architecture**" to describe the design and implementation of 6LoWPAN networks. This document will cover the concepts of "Mesh Under" and "Route Over", 802.15.4 design issues such as operation with sleeping nodes, network components (both battery- and line-powered), addressing, and IPv4/IPv6 network connections. **[Info]**

Charter 4/6

4. As a separate Internet Draft, "**6LoWPAN Routing Requirements**" will describe 6LoWPAN-specific requirements on routing protocols used in 6LoWPANs, addressing both the "route-over" and "mesh-under" approach. This document will be created and owned by this working group but is expected to be reviewed by the ROLL WG. **[Info]**

Charter 5/6

5. Produce "**Use Cases for 6LoWPAN**" to define, for a small set of applications with sufficiently unique requirements, how 6LoWPANs can solve those requirements, and which protocols and configuration variants can be used for these scenarios. The use cases will cover protocols for transport, application layer, discovery, configuration and commissioning. **[Info]**

Charter 6/6

6. Produce "**6LoWPAN Security Analysis**" to define the threat model of 6LoWPANs, to document suitability of existing key management schemes and to discuss bootstrapping/installation/commissioning/setup issues. This document will be referenced from the "security considerations" of the other 6LoWPAN documents. **[Info]**

72nd IETF: 6lowpan WG Agenda

09:00	**Introduction, Status**		**Chairs (20)**
09:20	**1 – Bootstrapping/ND optimization**		**(65)**
	0920	intro	Chairs
	0925	Commissioning update	KH Kim
	0929	ND opt update	S Chakrabarti
	0938	ND registration	E Nordmark
	0952	Whiteboarding	P Thubert
	1006	Route-over ND	J Hui
	1020	way forward	Chairs
10:25	**2 – HC**		**(20)**
10:45	**3 – Architecture**		**(10)**
10:55	**4 – Routing Requirements**		**(10)**

Commissioning and Bootstrapping

Network setup:

- **Commissioning: human intervention for setup**
  - **usually one time, e.g. configuration, special button, ...**
  - **might select major options in the protocol (e.g., MU/RO)**
  - **might e.g. include initial key setup**
  - **out of 6lowpan charter**
- **Bootstrapping: automatic steps for bootstrap**
  - **nodes find their place in the network (network entry)**
  - **might e.g. include authentication and transient keying**
  - **in 6lowpan charter**
- **What is the information being set up/agreed upon?**

Commissioning and Bootstrapping: Information set

- Keys (initial, transient; unicast/group)
- L2 vs. L3 routing?
- Routers, default routes
  - boundary to routing protocol unclear
- Coordinator election (if required)
- Prefixes, address (auto)configuration
- HC context
- _____

Protocols for Bootstrapping

- Where is the Information Set?
- Re-use (and change/mangle) ND, DHCPv6, ... vs. invent new, focused protocol (LBP)
- How expensive are these protocols
  - messages
  - code
- How stable is the usage of these protocols
  - for the new usage envisaged
  - in the dynamic lowpan environment

Roadmap for the next 60 minutes

- New protocol (and define information set)
  - draft-daniel-6lowpan-commissioning-02
- Optimize ND for mesh-under case
  - draft-chakrabarti-6lowpan-ipv6-nd-05
- Extend ND for information exchange
  - draft-nordmark-6lowpan-reg-00
  - draft-thubert-lowpan-backbone-router-01
- Extend ND for route-over case
  - draft-hui-6lowpan-nd-00

Commissioning in 6LoWPAN

draft-daniel-6lowpan-commissioning-02

Ki-Hyung Kim

S. M. Saif Shams

Seung Wha Yoo

Daniel Park

Geoff Mulligan

Before going into the details of Bootstrapping/Commissioning,

- We need to discuss and define the bootstrapping architecture, including
  - Bootstrapping Requirements and Design choices based upon 6lowpan Use cases

- Based upon that understanding, we could define/extend the necessary exchange protocol.

What is the necessary Bootstrapping/ Commissioning Information?

- Should it be different from WIFI or Ethernet? (because of no keyboard, no human intervention, low power, ad-hoc topology, etc)
  - Simplify existing protocols or re-design a light-weight protocol
- If there are multiple 6lowpans in POS, how the device select a PAN to join?
  - Is it just a matter of preference? or is it critical because of security or commissioning information?
  - PAN-ID, logical address
  - Server address

Should the bootstrapping be different in the open and closed (or secure) 6lowpans?

- Handling of authentication keys
- Do we allow that the bootstrapping traffic from the unauthenticated devices in 6lowpan which is basically in ad-hoc nature? (possible security threats?)

What is the necessary protocol?

- ND extensions, DHCP extensions, or define a light-weight LBP (bootstrapping protocol)?
- Where should the bootstrapping/ commissioning information be located?
  - IPv6 Routers, Separate LBS(Lowpan Bootstrapping Server, or every 6lowpan Routers

This Draft

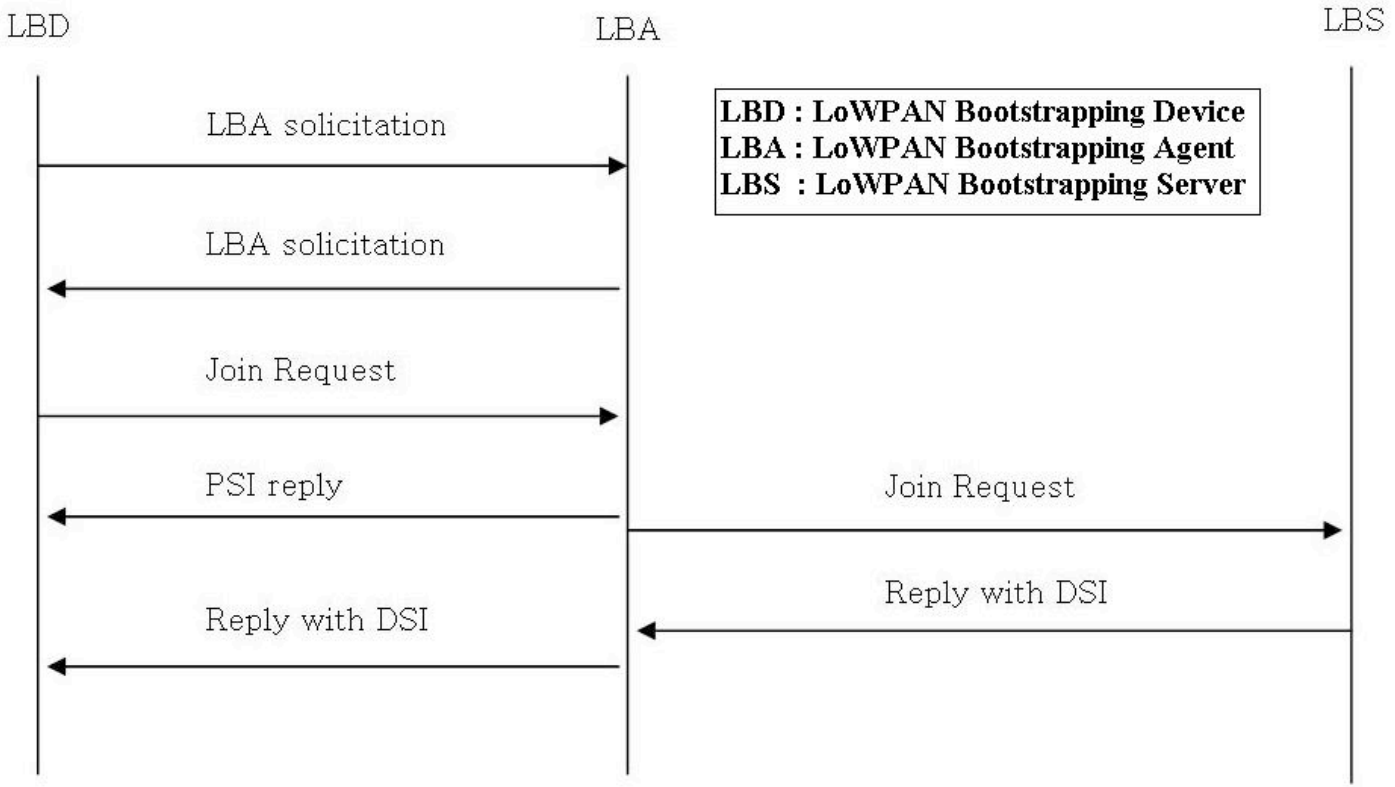
- Defines Lowpan Bootstrapping Information Base (LIB)
- Specifies the Bootstrapping procedure
  - Setting the beacon data structure (if it is a PAN-coordinator)
- Defines the basic operation of Lowpan Bootstrapping Protocol (LBP)
- Defines the short address assigning policies.
  - Centralized or Distributed Manner

Lowpan Bootstrapping Information Base (LIB)

- PAN-specific LIB (PSI)
  - PAN ID, Logical Channel
  - Prefixes
  - Bootstrapping Server Address
  - LBS address,
  - Routing
- Device-specific LIB (DSI)
  - Authentication Keys (in secured network)
  - Short Address,
  - Role of device, etc.

LoWPAN Bootstrapping Protocol (LBP)

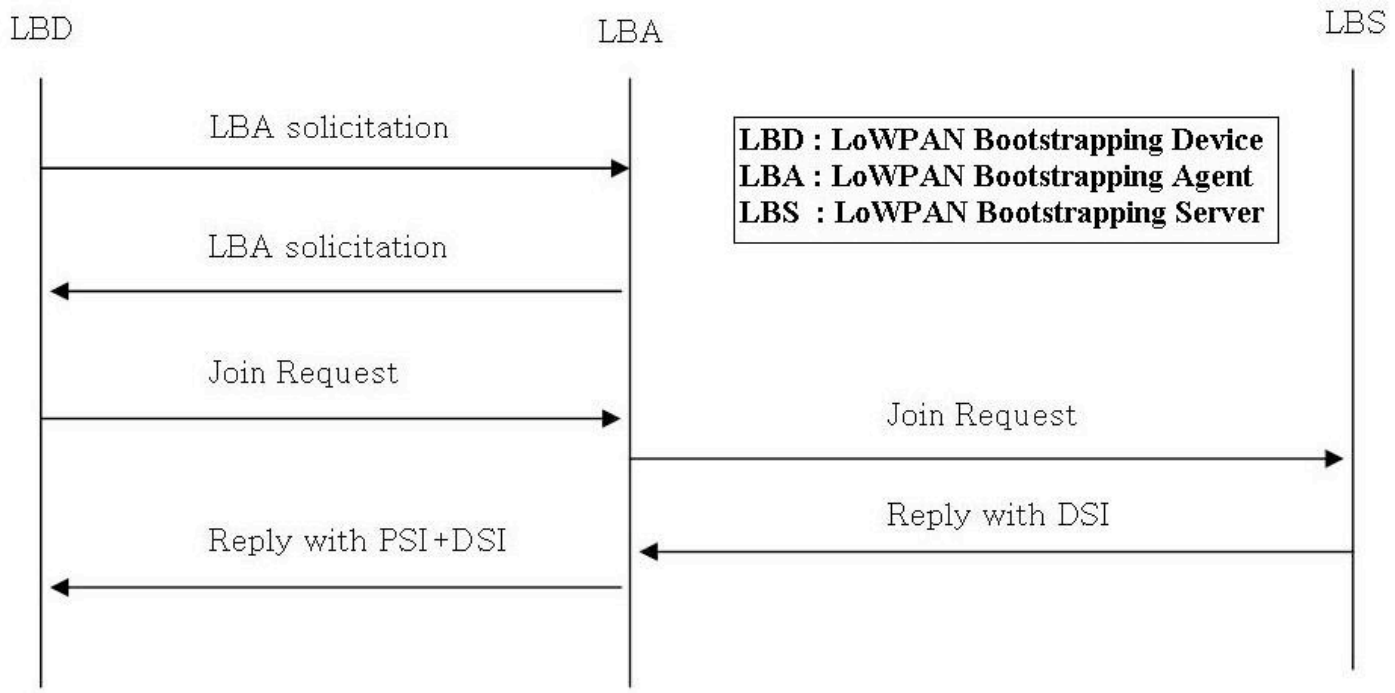
LBP In Open 6LoWPAN:



PSI: PAN specific information, DSI: Device specific information

LoWPAN Bootstrapping Protocol (LBP)

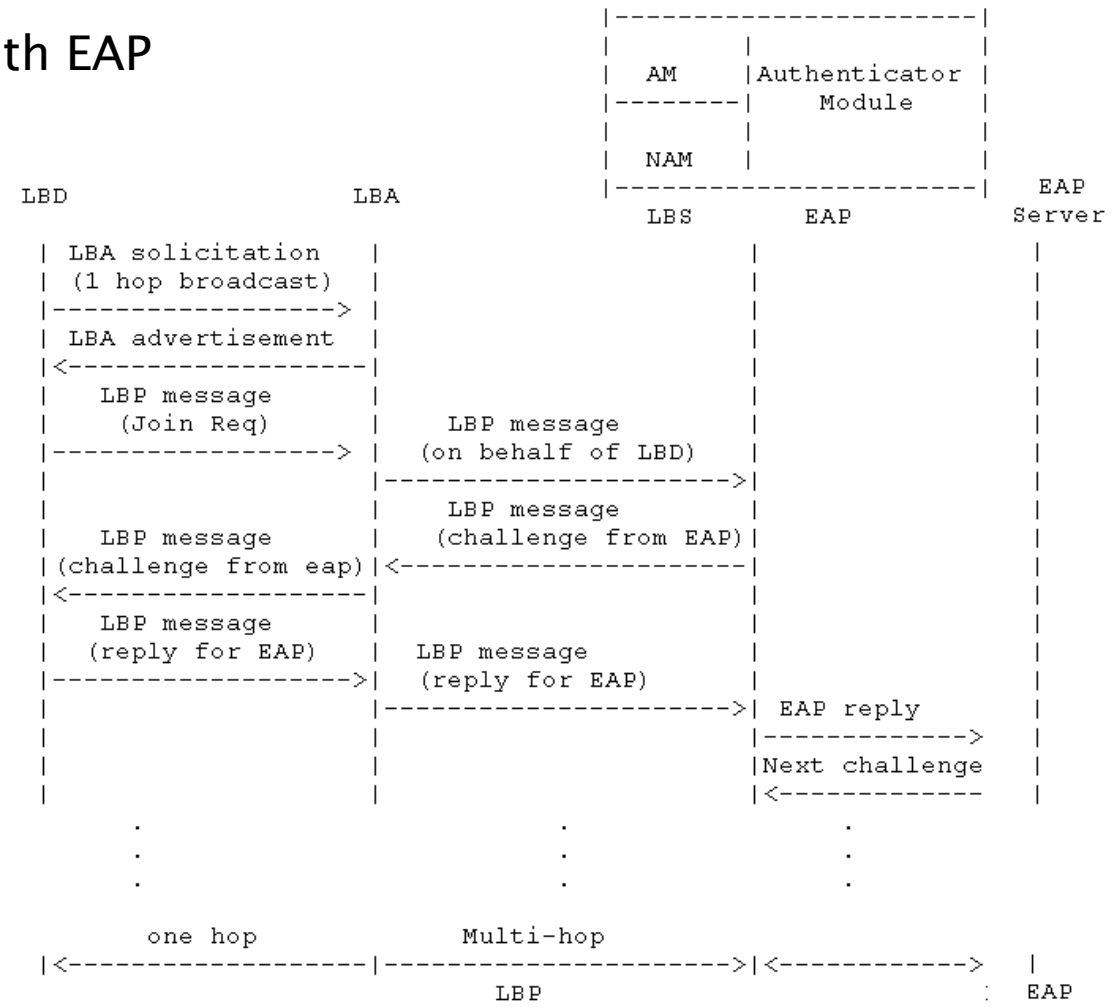
LBP In Close/Secure 6LoWPAN:



PSI: PAN specific information, DSI: Device specific information

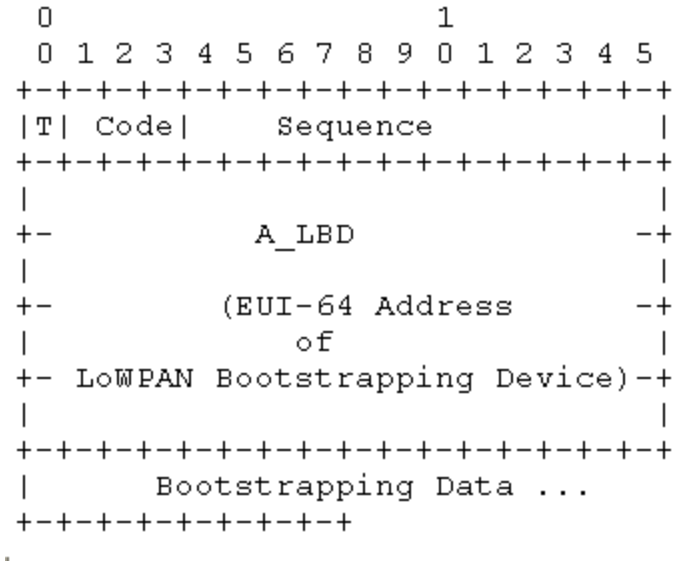
LoWPAN Bootstrapping Protocol (LBP)

Example: LBP with EAP



LoWPAN Bootstrapping Protocol (LBP)

LBP message format:



T:

0 = Message from LBD

1 = Message to LBD

Code:

001 = ACCEPTED. Authentication has been succeeded.

011 = DECLINE. Authentication has been failed.

010 = CHALLENGE. LBD should send another message

Seq : Sequence Number.

it identifies the number of messages transmitted/received by LBD.

A_LBD: Address of LBD

This field is used to identify the requesting device.

Bootstrapping Data: Variable length data.

[Described in the next slide]

PSI: PAN specific information, DSI: Device specific information

Summary

- Define the bootstrapping operation first and then do the protocol

- Comments and Suggestions

6lowpan ND Optimization draft 05

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IETF 72
July 29, 2008

draft-chakrabarti-6lowpan-ipv6-nd-05.txt

Document History

- The draft has been around since 2006
- Several versions were presented at the IETF working group meetings.
- Last presented at IETF 69, 2007

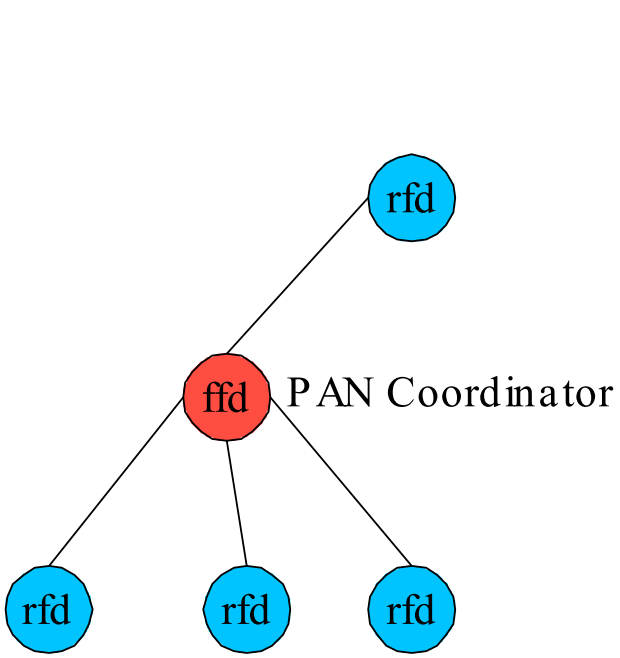
6Lowpan IPv6 ND Background

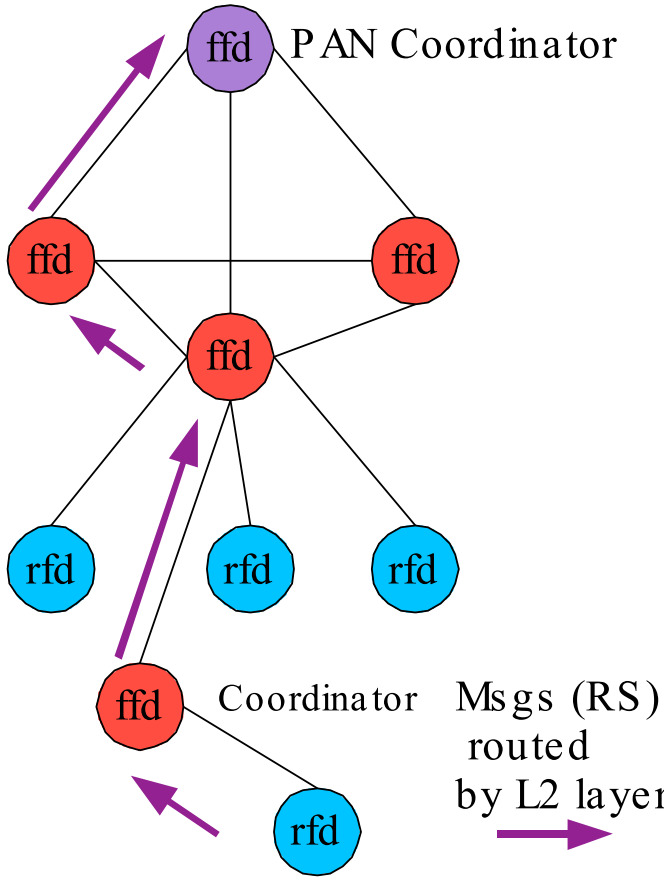
Main Goals for optimization

- Minimize multicast messa g es in RA, RS, NS and reduce un-needed unicast messages (NUD)
- Reduce or avoid DAD in 6lowpan network
- Mesh and star topologies are addressed

- Solution is applicable to other non-multicast networks
- Works with both L2 and L3 transport (although it describes L2-transport for 6lowpan-specific optimization)

Supported L2 topologies





Changes in draft 05

- **Added experimental values for a few ND variables**
- **Added a section on fault-tolerance to avoid a single IPv6-router**
- **Added sequence of operations in a typical 6lowpan network**
- **Addressed comments from Dave Thaler and Eunah Ensook**

Changes in draft 05

- **Experimental ND values**

  default maxRAadvtime 1500sec [higher value desirable]

  default RouterAdvLife 7200 sec [no less than 4500 sec]

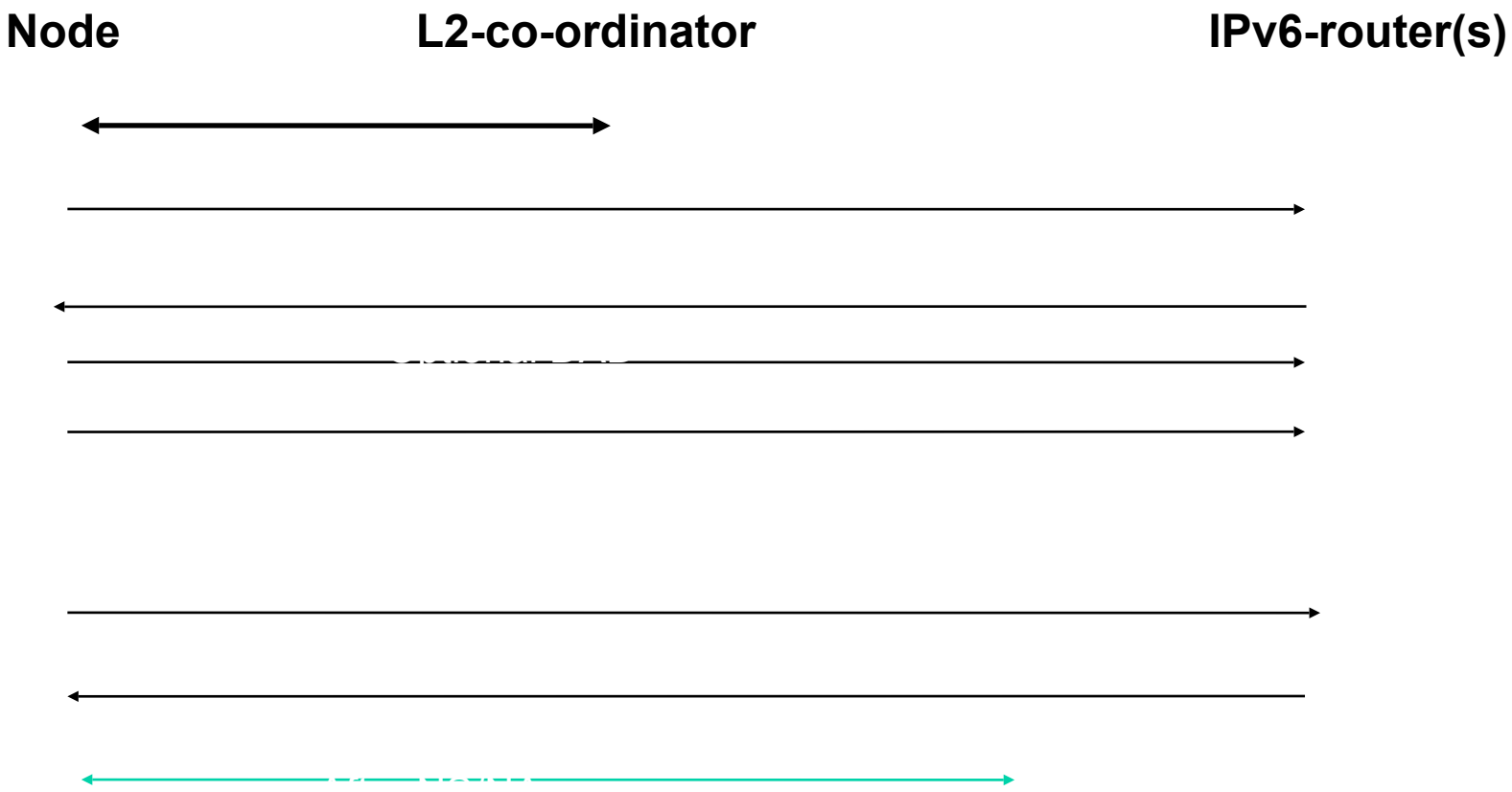
These values do not assume mobile network. We need to come up with Min/Max values for mobile/static networks respectively

- **Fault-tolerant IPv6-routers**

  Uses techniques used in draft-nordmark-6lowpan-reg-00 to send backup on-link IPv6-router's addresses along with RA

Changes in draft 05

Sequence of operation



Bootstrapping Information in this draft

IPv6 Bootstrapping requirements

- **Assignment of IPv6 prefix and default-router**
- **Auto-configuration and optional node-registration**
- **Assumes the node is dynamically or statically comissioned for IPv6-router information**
- **Any mechanism for access key and subsequent key derivation for secure ND is also not part of this document. They should be obtained through commissioning or other documents.**

Next Revision

To Do:

- Handle short addresses (?)
- Use anycast for Router Solicitation
- Remove PAN coordinator assumption (it is just an example)
- Cleaning up open issues
- Finalize default values

NOTE:

Support for full-mesh topology may require running IPv6-routers at each co-ordinators. This introduces network-load and packet overhead in the low-power network.

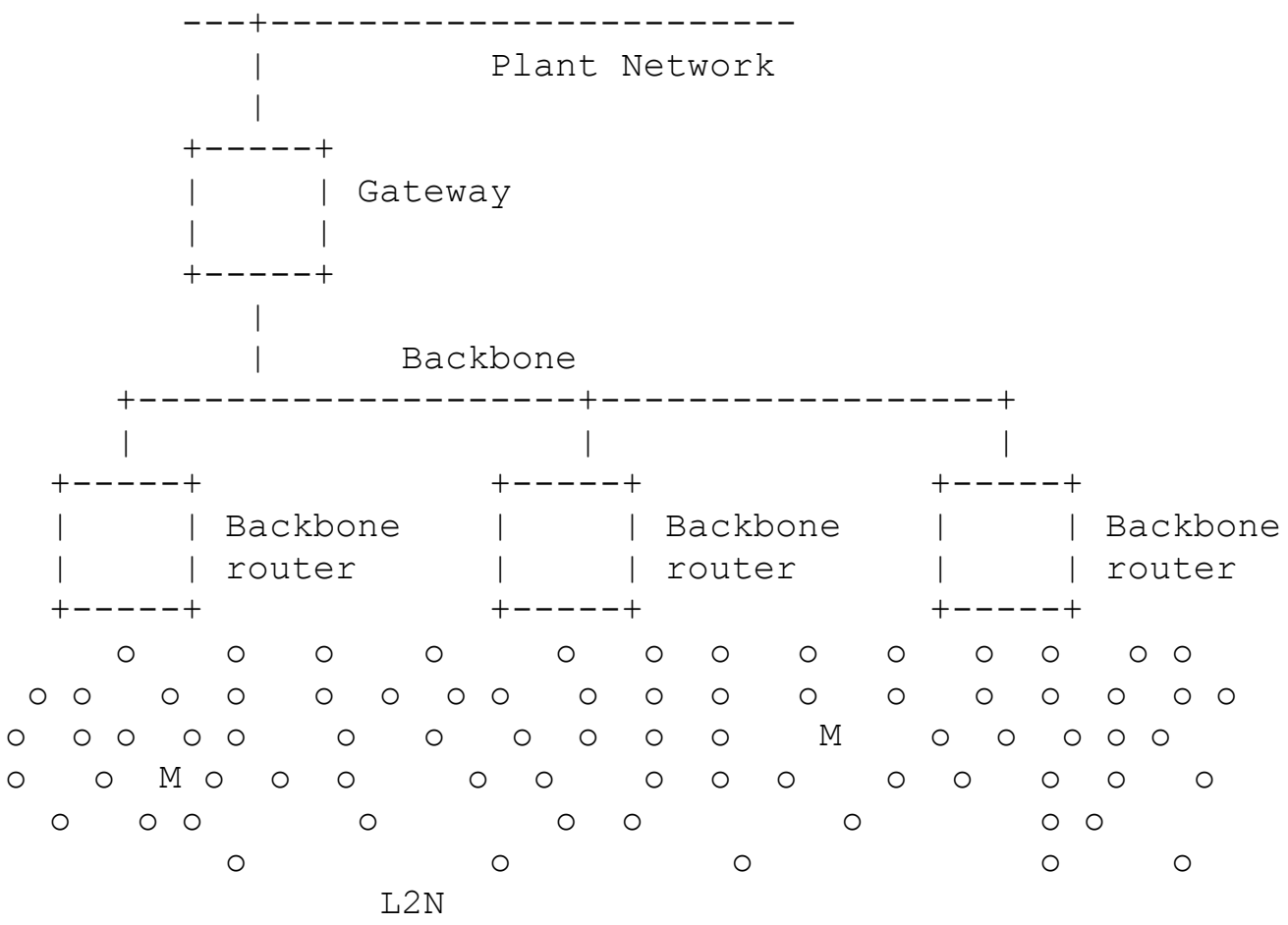
Comments?

(EN)

6LoWPAN Backbone Router

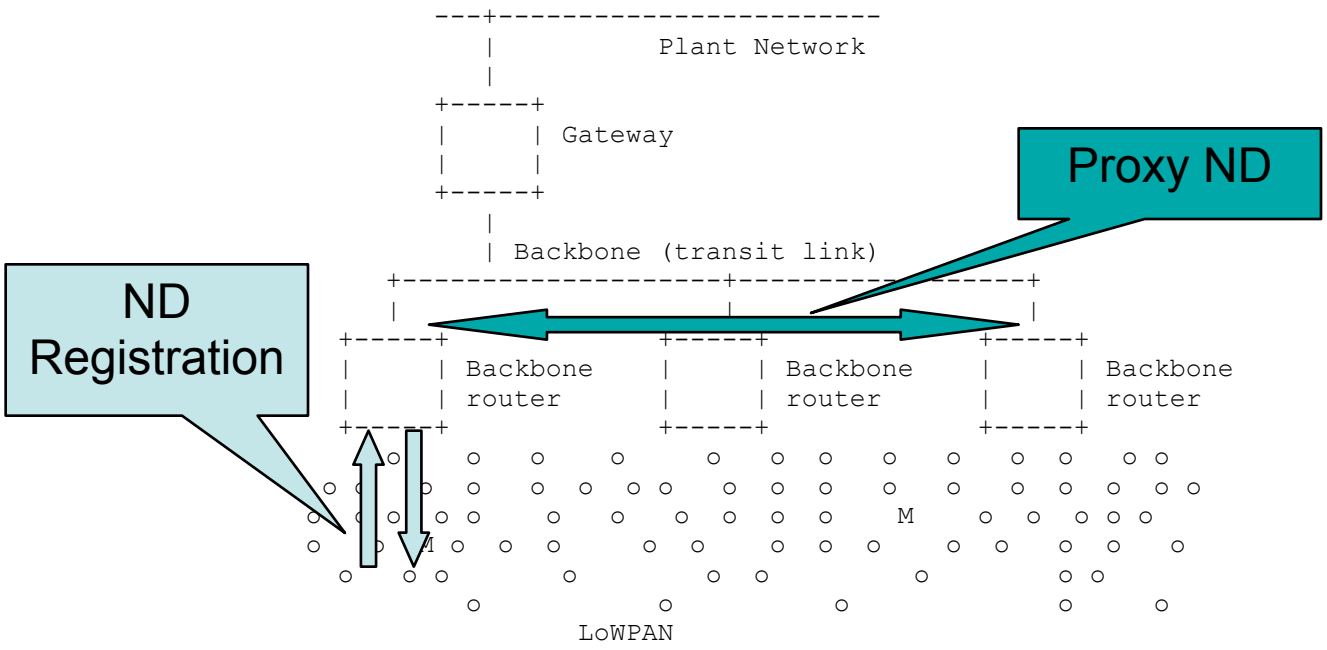
P Thubert IETF 72

Physical topology (from ROLL industrial routing requirements)



draft-thubert-6lowpan-backbone-router

- New ICMP Registration ND messages
  - for proactive stateless autoconfiguration
- Proxy ND on a backbone that federates the LoWPANs



Eliminate ND mcast

- Avoid RAs
  - Rely on ANYCAST functional address
  - Mapped by default with coordinator/AP
- Avoid NS/NA
  - New Unicast registration mechanism
  - From an ANYCAST (or optimistic) address
  - To a white board (backbone router)
  - BbR performs proxy ND to protect the node

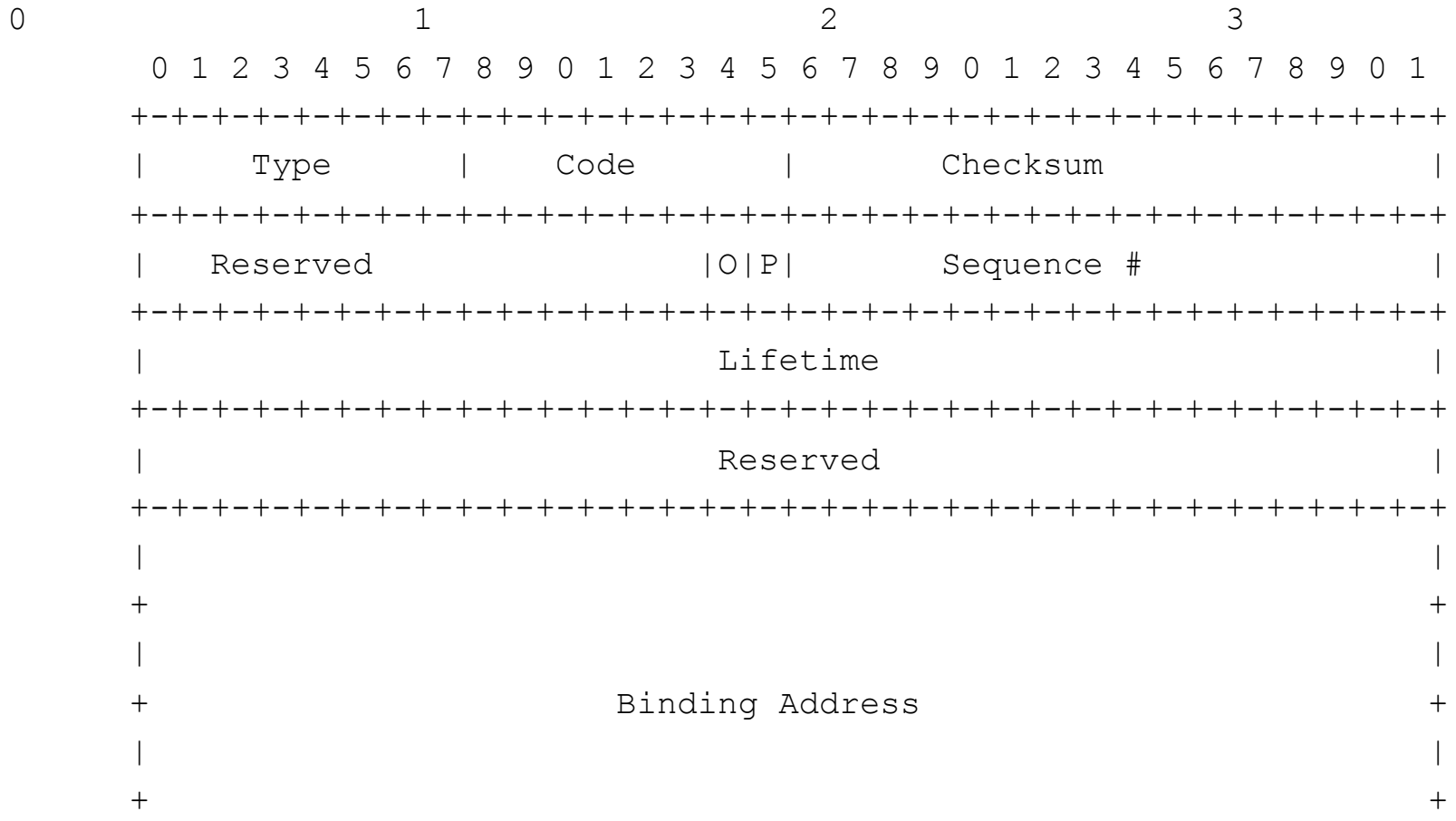
White Board vs. Cry Out Loud

- ND as a reactive routing protocol
  - On demand host route lookup
  - Over one link
  - Based on Multicast (often MAC broadcast)
  - Sleeping nodes?
- Vs. Stateful (Registration)
  - Proactively installs states on powerful routers
  - Capable to proxy while node is sleeping
  - Single point of failure? Bottleneck?

New stuff

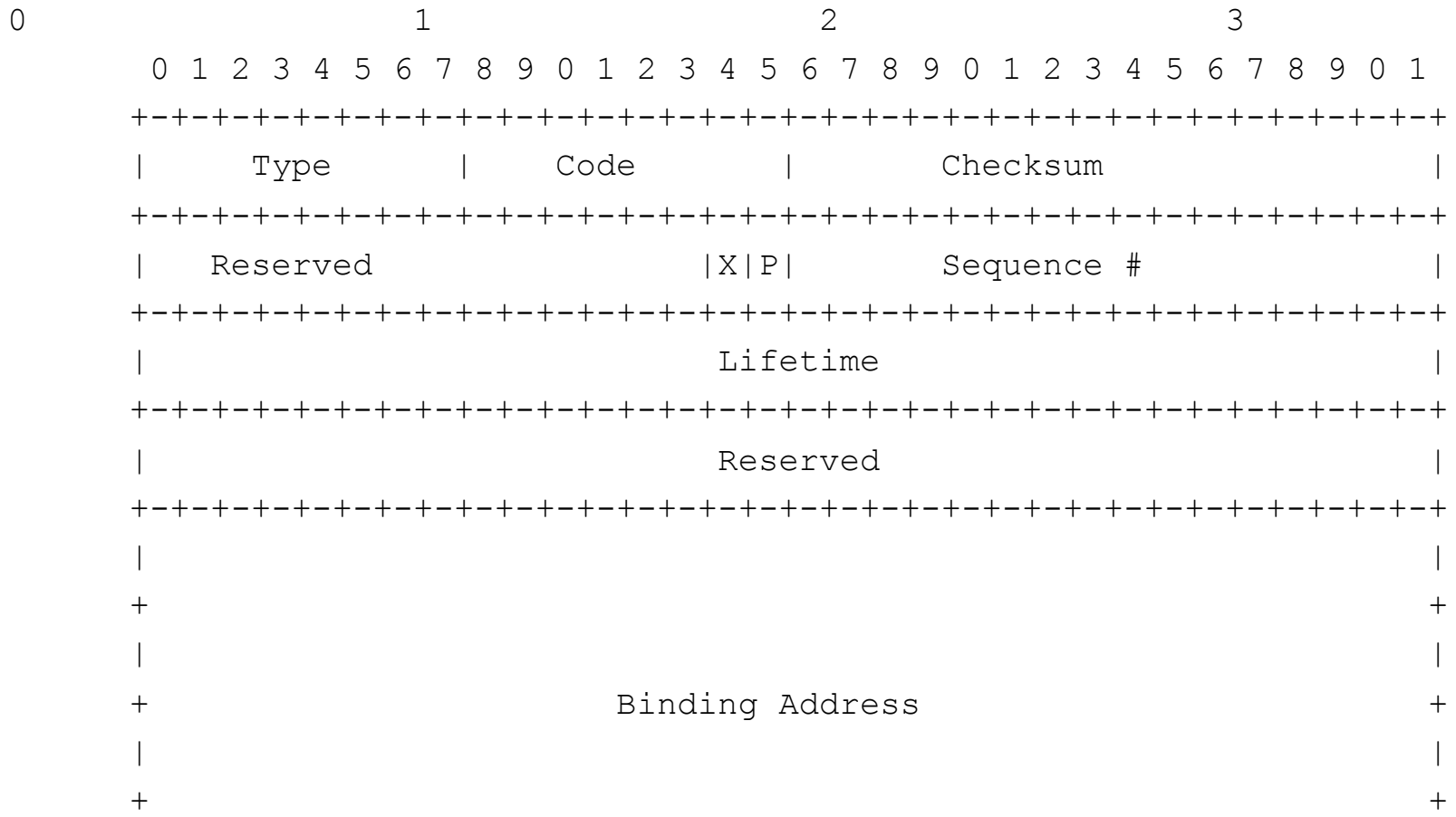
- ICMP messages for the binding flows
  - Binding Solicitation
  - Binding Acknowledgement
  - Concept of a primary BbR
- Well known anycast addresses
  - 6LOWPAN_BBR for the routers
  - 6LOWPAN_NODE the nodes
  - Reserved link local unicast addresses
  - Acting as Functional Addresses

Binding Solicitation



P: Primary Flag. Set to indicate that the router is primary and MAY proxy ND
O: Optimistic Flag. Set if the node uses oDAD and accepts packets on the BAddr

Binding Confirmation



P: Primary Flag. MUST echo the P flag in the Binding solicitation.
X: Proxy Flag. Set if the route actually proxies ND for the node

Proxy ND operation

- Inherited from MIP (RFC 3775/bis)
  - HA is a proxy on the Home Link
- Respect RFC 4389
  - MTU Issue
- Still a lot of TBD
  - Eg use of override in NA by the proxy:
    - BbR recommends not to set it
    - But during upon a flow with the owner device

Please read

- Draft-ietf-roll-indus-routing-reqs
  - ROLL requirements for industrial
- RFC 4389
  - ND Proxy
- draft-ietf-mext-rfc3775bis
  - re-MIP
- Also visit ISA100
  - http://www.isa.org/MSTemplate.cfm?MicrositeID=1134&CommitteeID=6891

????? Questions ?????

Neighbor Discovery and Autoconf for Route-Over 6LoWPAN Networks

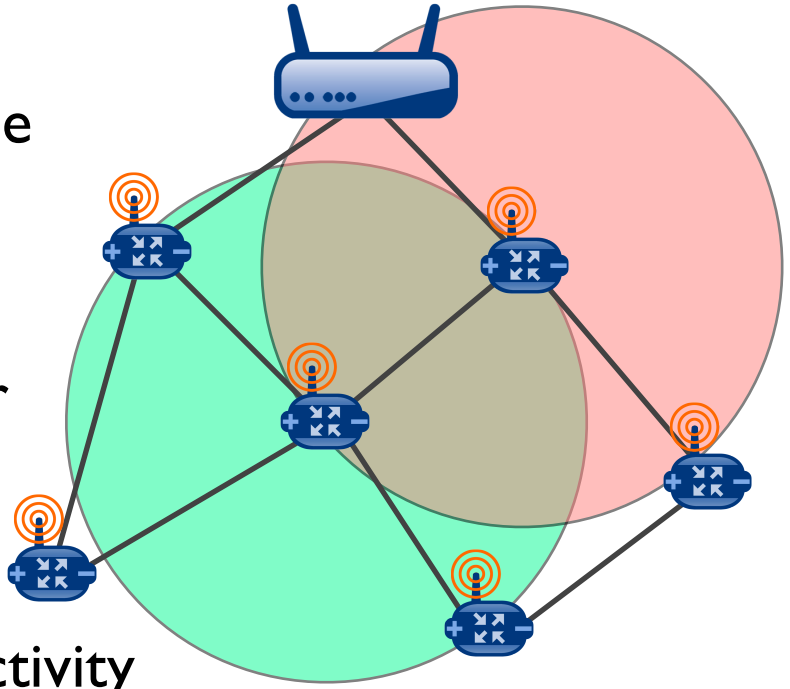
(draft-hui-6lowpan-nd-00.txt)

Jonathan Hui

6LoWPAN WG Meeting
72nd IETF Meeting
Dublin, Ireland

Route-Over Configuration

- Radio Range <=> Link-Local Scope
  - Network of overlapping link-local scopes
  - No transitive reachability
- Every node may be an IPv6 router
  - 6LoWPAN Router - Single 802.15.4 interface
  - Border Router - Connects different media
- IP-level visibility into radio connectivity
  - Address radio neighbors using link-local addresses
  - Discover radio neighbors with link-local multicast
  - No need to join an L2 network to communicate at L3



6LoWPAN ND and Autoconf

- RFC 4861
  - Defined for operation over a single IPv6 link
  - Relatively high overhead (Address Resolution, NUD, DAD)
  - Assumes transitive reachability

- 6LoWPAN ND and Autoconf Summary
  - Bare minimum to configure and bootstrap a 6LoWPAN network
  - Discover routers (but does not define a routing protocol!)
  - Configure nodes with Border Router as configuration point
    - propagate prefix, context, and other parameters over multiple hops
    - support both stateless and DHCPv6 configuration models
  - Respect low-power, lossy links with small MTU!

Addressing Model

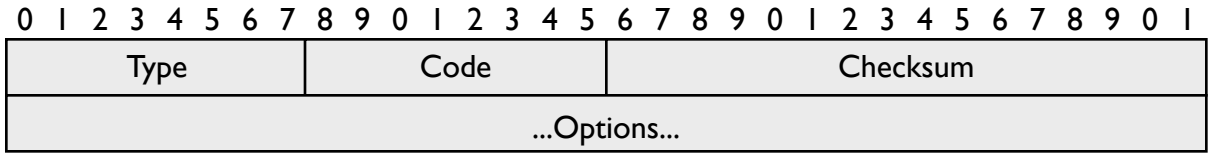
- IID MUST be derived from IEEE 802.15.4 addrs
  - No address resolution protocol and caches
  - Global scope - IEEE EUI-64
  - Local scope - Short Address
- Uniqueness maintained by other mechanisms
  - Manual configuration, PAN Coordinator, DHCPv6, routing, etc.
  - No duplicate address detection in ND/autoconf
- IPv6 addresses from a common set of prefixes
  - Enable context-based HC
  - But nodes do not need an address for every prefix
- Only border router accepts subnet router anycast
  - 6LoWPAN Routers only assign /128 to their interface
  - Allow nodes to address Border Router

ND Summary

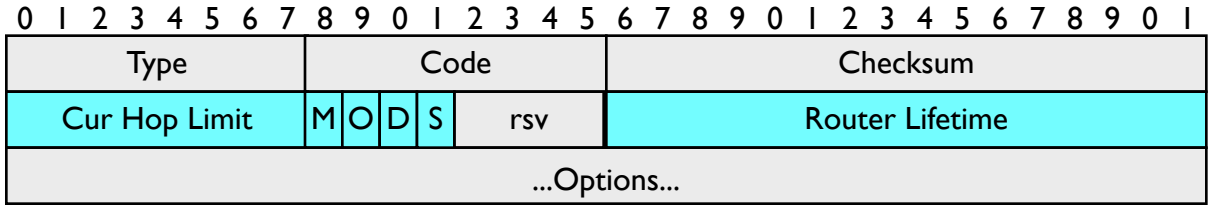
- Nodes disseminate info using RA messages
  - Always accept newer sequence number
  - Advertise latest information in RA messages
- Manage RA transmissions using Trickle (NSDI '04)
  - Reliable with quick propagation and low overhead in steady state
  - Transmission period (T) bounded by [Tlow, Thigh]
  - With each transmission, double T up to Thigh
  - When any sequence number differs:
    - Reset T to Tlow
    - Include differing prefix information option in next RA transmission

ND Messages

- Router Solicitation (4 bytes)



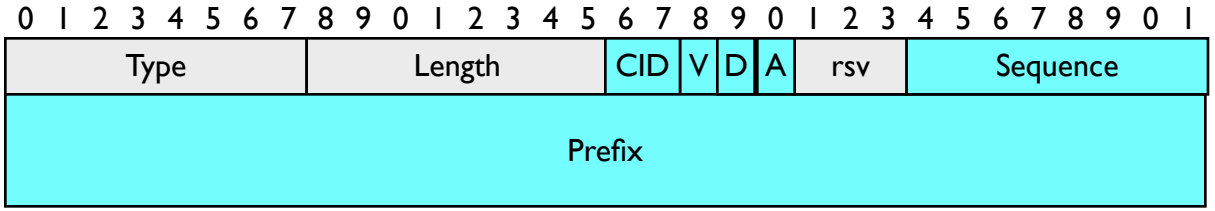
- Router Advertisement (8 bytes)



  - Cur Hop Limit - value to put in outgoing messages
  - M - Managed address configuration
  - O - Other configuration
  - D - DHCPv6 Server/Relay
  - S - Solicitation
  - Router Lifetime - indicates lifetime of router

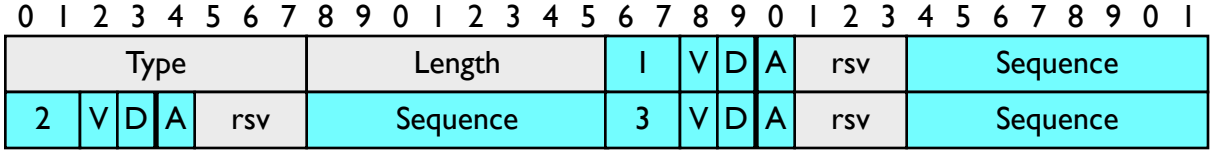
RA Options

- Prefix Information Option (12 bytes)



  - CID - context identifier for use with HC
  - V - valid prefix information
  - A - to use for address autoconfiguration
  - D - deprecated (to phase out prefix information)
    - Do not use as IPv6 source address
    - Continue to accept messages
  - Sequence - nodes always accept prefix information with latest sequence

- Prefix Summary Option (8 bytes)



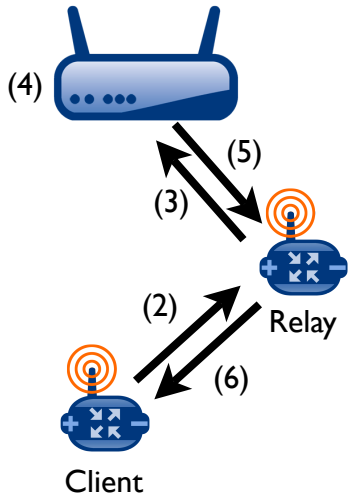
Stateless Address Autoconf

- Prefixes
  - Link-local - well-known
  - Global - from Prefix Information Option
- Interface Identifiers
  - Global Scope: IEEE 802.15.4 Extended Address (IEEE EUI-64)
  - Local Scope: IEEE 802.15.4 Short Address

DHCPv6

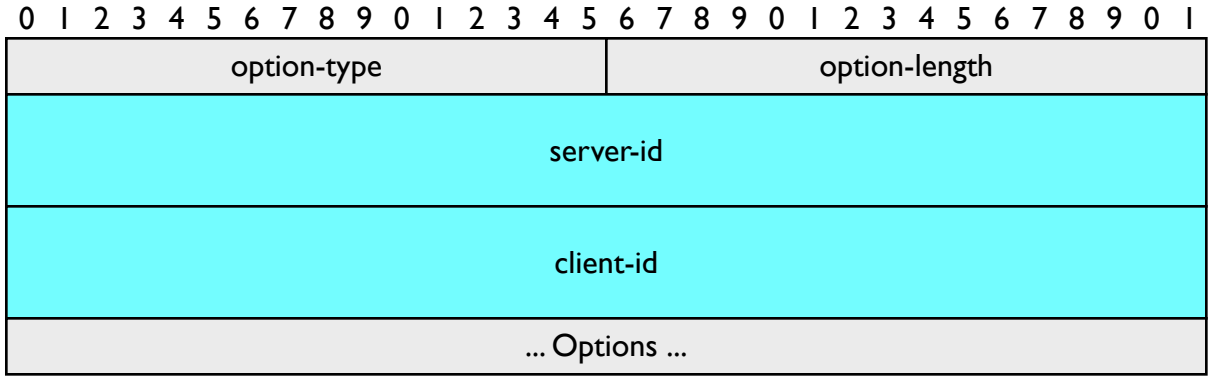
- Centralized control and management
  - Mechanism for short address assignment
  - Maintains basic DHCPv6 protocol (but with compression techniques)
  - But requires routes to the Border Router

- 6LoWPAN Routers act as DHCPv6 Relays
  1. RA messages announce availability of DHCPv6 Relays
  2. Link-local unicast request to DHCPv6 Relay
  3. Relay forwards requests to 6LoWPAN Border Router
  4. Border Router may host DHCPv6 Server or Relay
  5. Border Router sends reply to DHCPv6 Relay
  6. DHCPv6 Relay responds to DHCPv6 Client



DHCPv6 Option Formats

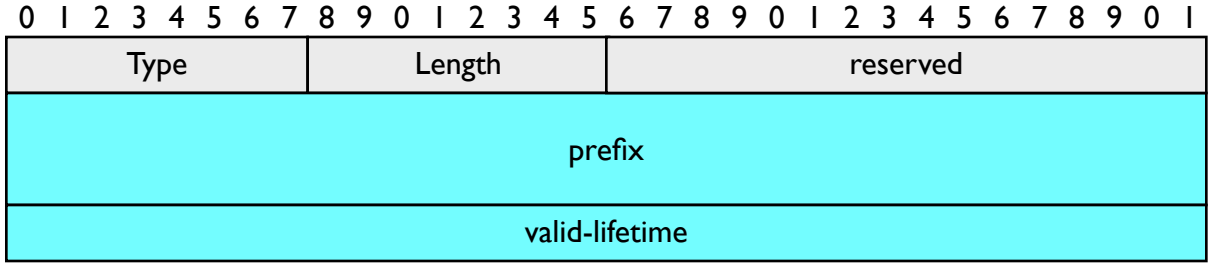
- IA_6LOWPAN Option (20 bytes)



  - Simplified Identity Association format
  - Assumes only one IAID
  - T1 and T2 are not included (instead, rely on reconfigure)
  - server/client-id - DUID but MUST be IEEE EUI-64
  - No DHCPv6 Relay header when relaying between 6LoWPAN Router and Border Router
    - Derive link/peer-address from server/client-id

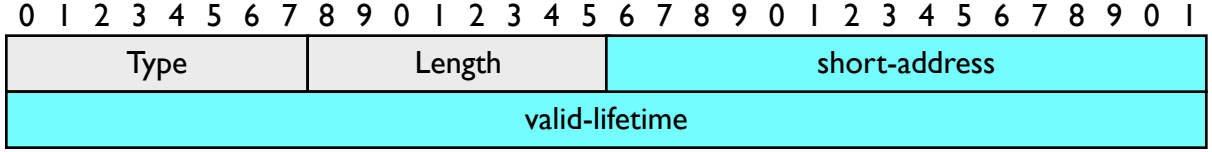
DHCPv6 Option Formats

- IA_6LOWPAN Prefix Option (16 bytes)



  - prefix - global routing prefix for IPv6 address
  - valid-lifetime - valid lifetime for IPv6 addresses using the prefix

- IA_6LOWPAN Local IID Option (8 bytes)



  - short-address - IEEE 802.15.4 short address
  - valid-lifetime - valid lifetime for the short address

Summary

- Goal
  - ***Simple*** ND and autoconf for ***route-over*** 6LoWPAN while respecting low-power, lossy links and small MTUs
- Simplified Neighbor Discovery
  - Compact Router Advertisements/Solicitations
  - Trickle-based transmission period
  - Prefix information (HC and SLAAC)
  - No Address Resolution, NUD, DAD, and Redirect
- DHCPv6 (with compressed options)
  - Compact DHCPv6 Options
  - IPv6 address assignment
  - Short address assignment
  - Routers <=> DHCPv6 Relay
  - Border Routers <=> DHCPv6 Server/Relay

Discussion

- Is this a good idea?
- Comments and suggestions?

72nd IETF: 6lowpan WG Agenda

09:00	**Introduction, Status**		**Chairs (20)**
09:20	**1 – Bootstrapping/ND optimization**		**(65)**
10:25	**2 – HC**		**(20)**
	1025	HC-01 intro	J Hui
	1030	CBHC	C Bormann, J Hui
10:45	**3 – Architecture**		**(10)**
10:55	**4 – Routing Requirements**		**(10)**
11:05	**5 – Use cases**		**(10)**
11:15	**6 – Security**		**(10)**
11:25	**0 – unchartered**		**(15)**

Compression Format for IPv6 Datagrams in 6LoWPAN Networks

(draft-hui-6lowpan-hc-01.txt)

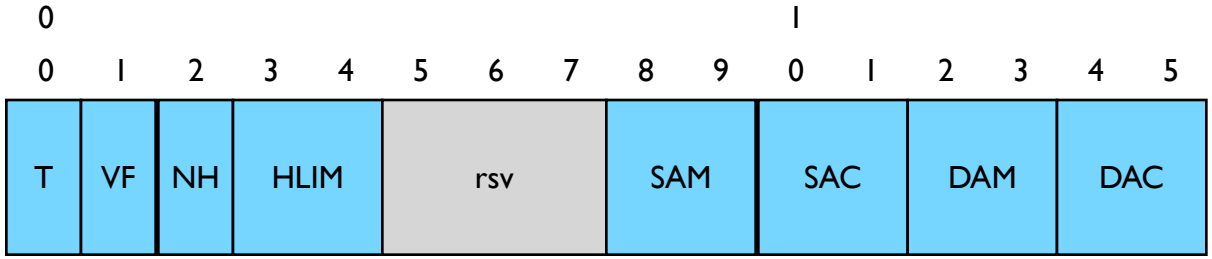
Jonathan Hui

6LoWPAN WG Meeting
72nd IETF Meeting
Dublin, Ireland

Changes

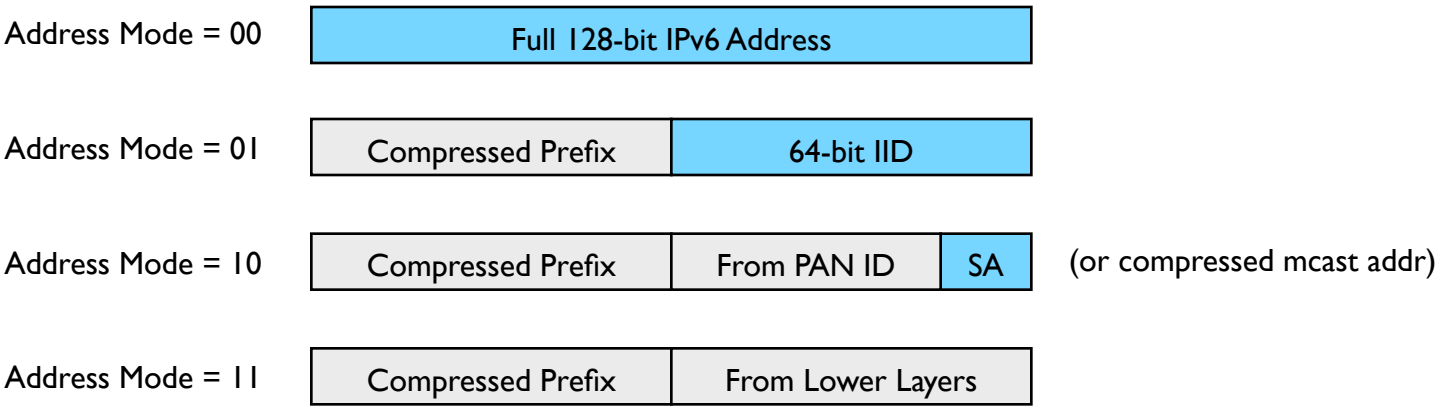
- 2 bits for HLIM compression
- Multiple contexts for addr compression
- Split Traffic Class and Flow Label compression
- UDP checksum

IPv6 Header Compression



T	Traffic Class	0 = Inline, 1 = Compressed
VF	Version and Flow Label	0 = Inline, 1 = Compressed
NH	Next Header	0 = Inline, 1 = Compressed
HLIM	Hop Limit	00 = Inline, 01 = 1, 10 = 64, 11 = 255
SAM	Source Address Mode	00 = Inline, 01 = 64, 10 = 16, 11 = 0
SAC	Source Address Context	00 = Link-Local
DAM	Destination Address Mode	00 = Inline, 01 = 64, 10 = 16, 11 = 0
DAC	Destination Address Context	00 = Link-local

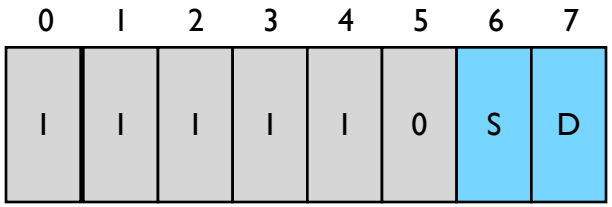
IPv6 Address Compression



- 2-bit address mode - how many bits carried inline
- 2-bit context identifier - what prefix to use
  - 00 - reserved for link-local prefix
  - See draft-hui-6lowpan-nd-00.txt for initial thoughts on how to distribute context information

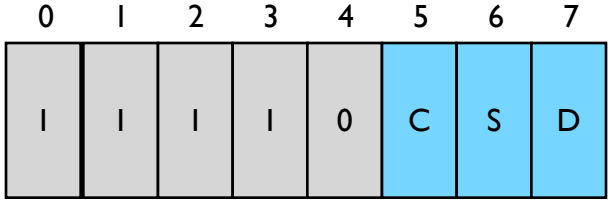
UDP Header Compression

LOWPAN_UDP



ID	111110	
S	Source Port	0 = Inline, 1 = Compressed
D	Dest Port	0 = Inline, 1 = Compressed

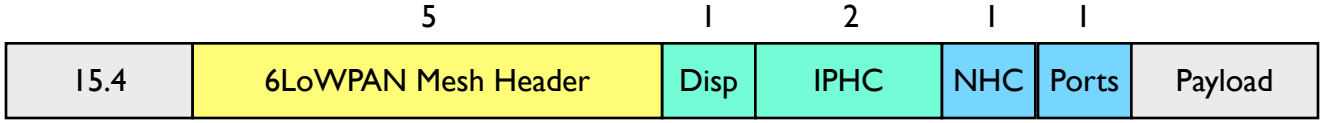
ISA100_UDP



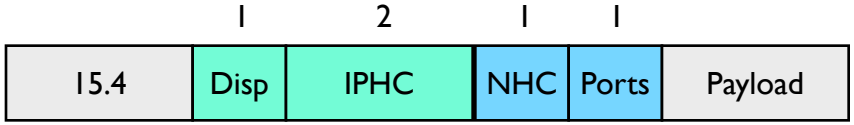
ID	11110	
C	Checksum	0 = Inline, 1 = Compressed
S	Source Port	0 = Inline, 1 = Compressed
D	Dest Port	0 = Inline, 1 = Compressed

Unicast Examples

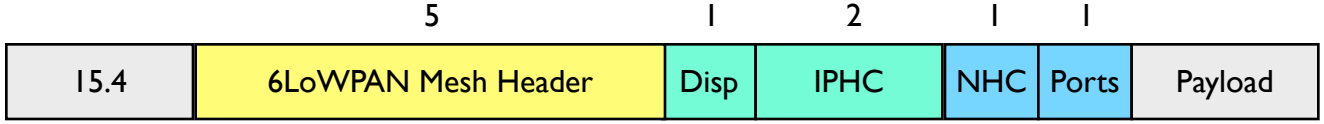
- Link-Local, Mesh Under (10 bytes)



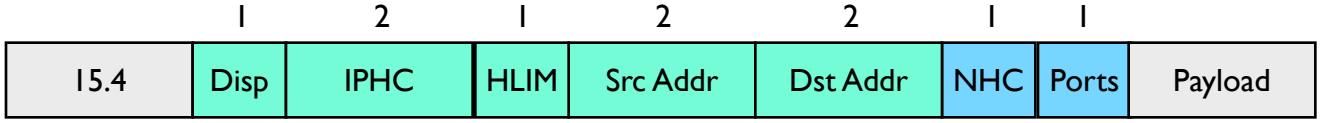
- Link-Local, Route Over (5 bytes)



- Global, Mesh Under (10 bytes)

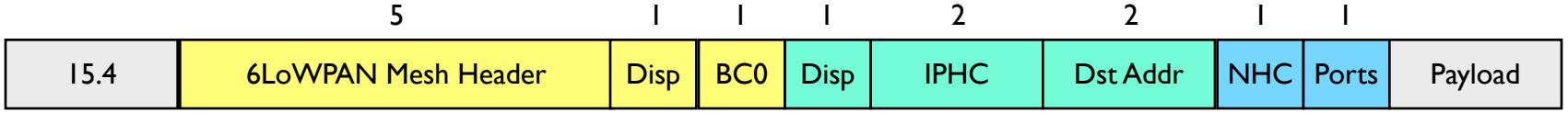


- Global, Route Over (10 bytes)

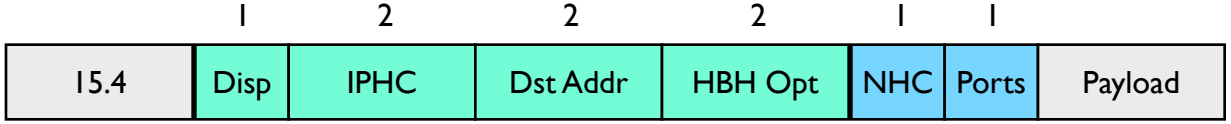


Multicast Examples

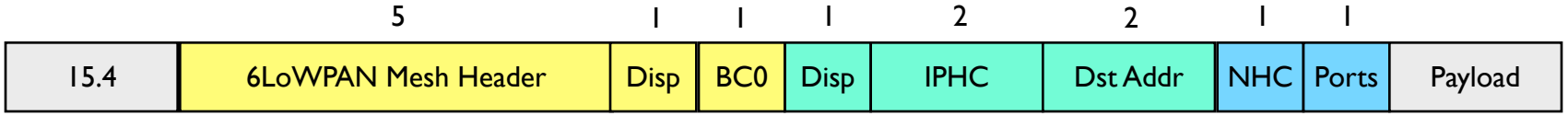
- Link-Local, Mesh Under (14 bytes)



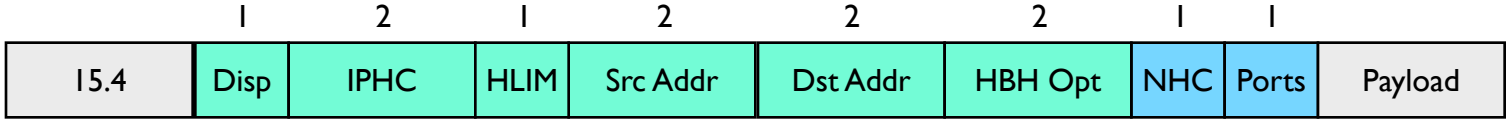
- Link-Local, Route Over (9 bytes)



- Global, Mesh Under (14 bytes)



- Global, Route Over (12 bytes)



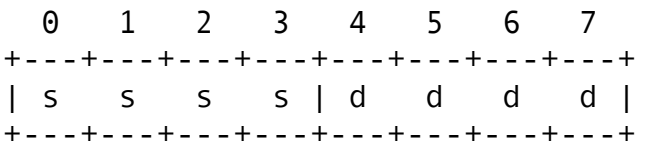
Discussion

- Should HC become a WG doc?
- Deprecate LOWPAN_HC1/HC2?

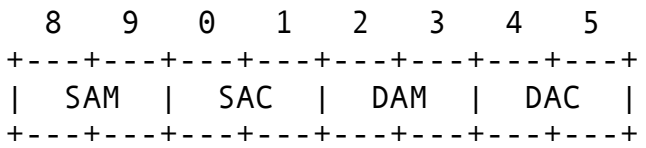
Context-based HC

- **How to compress global prefixes?**
  - **Sender and receiver need to agree on just what that is**
  - **establish common state → Context**
- **Which protocol to use to obtain agreement?**
  - **new: draft-ietf-nordmark-6lowpan-reg**
  - **establishes state between node and registrars**
- **Protocol operation:**
  - **add context to registration option in RA**
  - **add acknowledgement in Registration**
  - **make sure context is only used when established**
    - may need long timeouts on config change (renumbering)

What is the information set



- **CBHC proposal:**
  - **up to 15 entries, number implies format:**
    - 0 0 (uncompressed)
    - 1-3 TBD
    - 4-7 /64
    - 8-11 /112
    - 12-15 /128
  - **compressed address = 4 bits**



- **HC-01 proposal:**
  - **up to 3 entries (00 = link-local)**
  - **compressed address = mode (2 bits), context (2 bits)**

Examples

- **node-outbound:**
  - **SA = global prefix(64)/IID (0 bits)**
  - **DA = correspondent prefix (128 or 64 or 16 down to 0 bits!)**
  - **packet from node to router, which have agreed on context**
- **inbound-node**
  - **inverse**
- **node-node**
  - **nodes never have agreed → can't compress global prefixes!**
  - **idea: add "context accepted" bit in NA**

72nd IETF: 6lowpan WG Agenda

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10:45	**3 – Architecture**	**(10)**
1045	Mobility	C Williams
1050	MIB	KH Kim, C Bormann
10:55	**4 – Routing Requirements**	**(10)**
11:05	**5 – Use cases**	**(10)**
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11:25	**0 – unchartered**	**(15)**

Mobility Considerations for 6LoWPAN

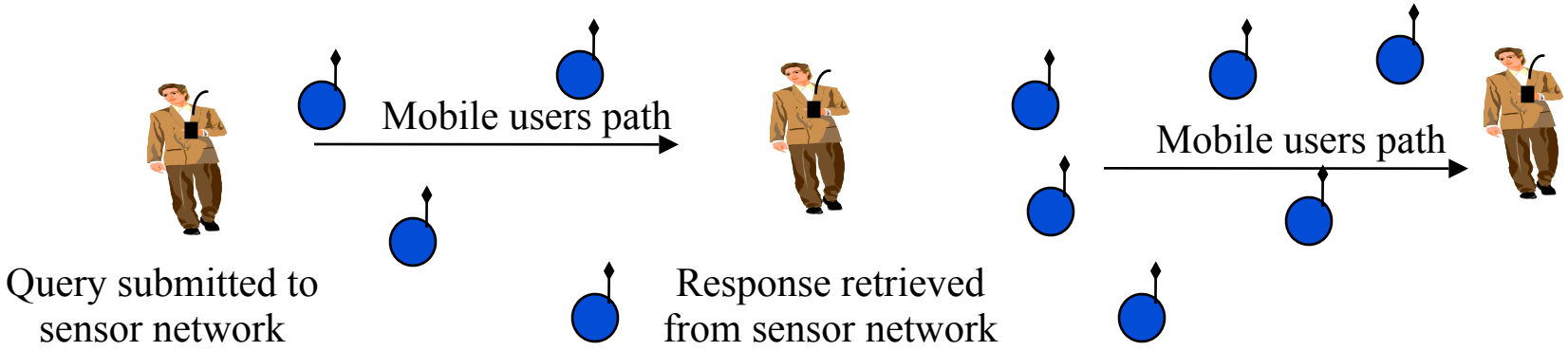
Work item 3

"6LoWPAN Architecture"

Geoff Mulligan
Carl Williams
David Huo

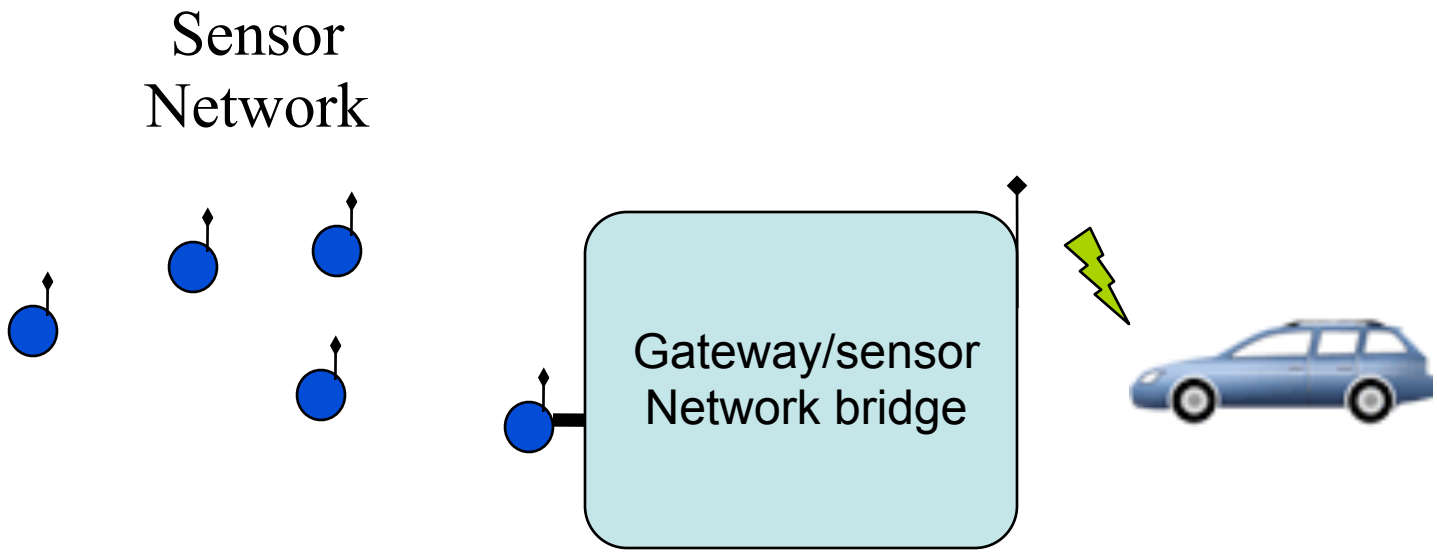
Mobility considerations

- Mobile users will need to inject a sensor query into the 6LoWPAN network while they are mobile.
- Mobile users will also need to retrieve a sensor response from the 6LoWPAN network while they are mobile.



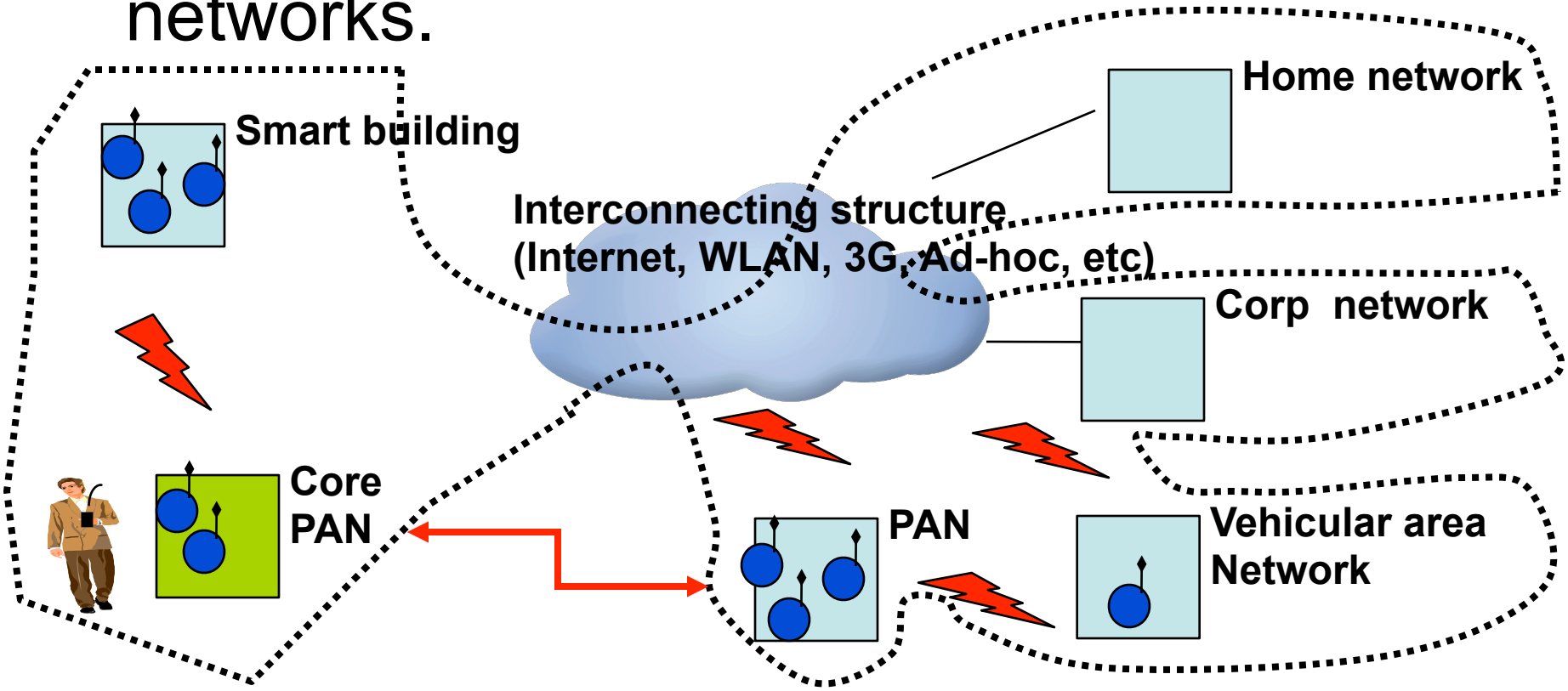
Mobility Considerations - Global Reachability -

- Architecture to provide global reachability to the 6LoWPAN nodes no matter where the correspondent peers are located, and no matter what their point of attachment is.



Mobility considerations - interconnection framework -

- Mobility will also play a role in the future interconnection framework for 6LoWPAN networks.

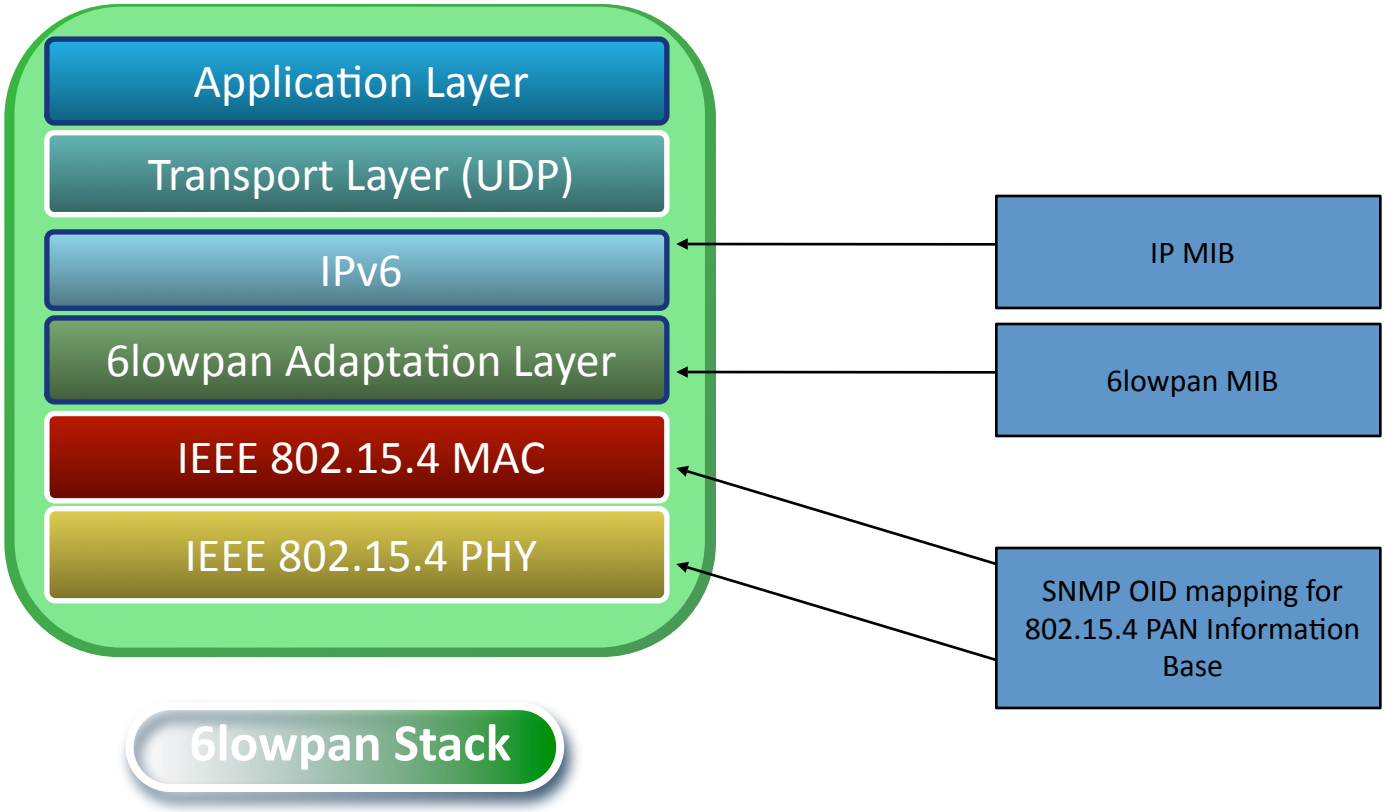


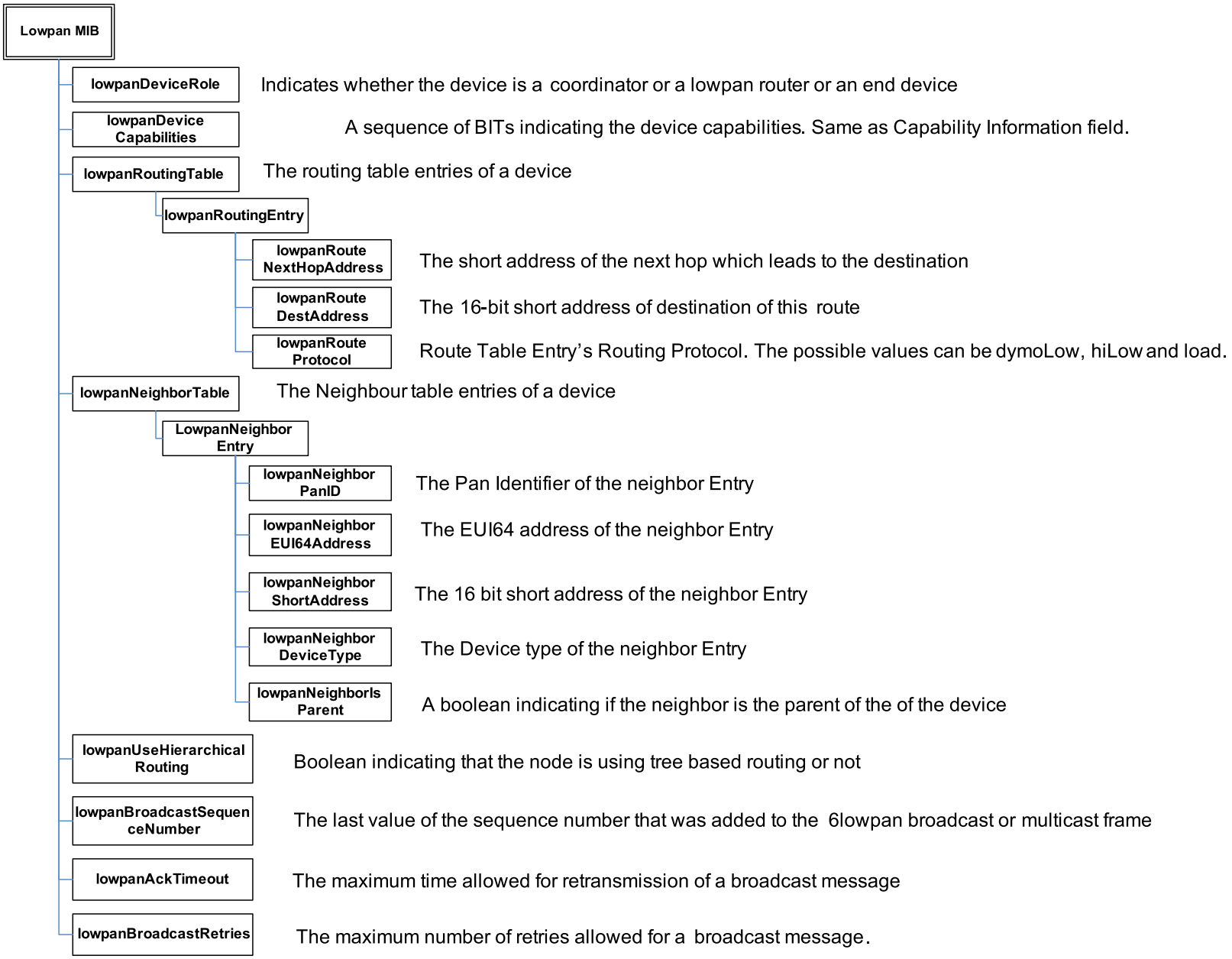
Next Steps

- Mobility should be a consideration upfront rather than an after thought in the development of 6LoWPAN milestones.
- Separate document or include in base architecture document.

MIB for 6lowpan?

- **draft-daniel-lowpan-mib-01.txt**
-




Lowpan MIB
lowpanDeviceRole
Indicates whether the device is a coordinator or a lowpan router or an end device
lowpanDevice Capabilities
A sequence of BITs indicating the device capabilities. Same as Capability Information field.
lowpanRoutingTable
The routing table entries of a device
lowpanRoutingEntry
lowpanRoute NextHopAddress
The short address of the next hop which leads to the destination
lowpanRoute DestAddress
The 16-bit short address of destination of this route
lowpanRoute Protocol
Route Table Entry's Routing Protocol. The possible values can be dymoLow, hiLow and load.
lowpanNeighborTable
The Neighbour table entries of a device
LowpanNeighbor Entry
lowpanNeighbor PanID
The Pan Identifier of the neighbor Entry
lowpanNeighbor EUI64Address
The EUI64 address of the neighbor Entry
lowpanNeighbor ShortAddress
The 16 bit short address of the neighbor Entry
lowpanNeighbor DeviceType
The Device type of the neighbor Entry
lowpanNeighborIs Parent
A boolean indicating if the neighbor is the parent of the of the device
lowpanUseHierarchical Routing
Boolean indicating that the node is using tree based routing or not
lowpanBroadcastSequenceNumber
The last value of the sequence number that was added to the 6lowpan broadcast or multicast frame
lowpanAckTimeout
The maximum time allowed for retransmission of a broadcast message
lowpanBroadcastRetries
The maximum number of retries allowed for a broadcast message.

Is this the right approach?

- Using SNMP to control battery-operated devices?
  - pull-model
  - ASN.1 scare
  - large number of addressable items
  - SNMPv3 e2e security may be too heavyweight
- If not, what are the right management models?
  - lightweight e2e?
  - proxy model?

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	1055 Routing Requirements	E Kim
11:05	**5 – Use cases**	**(10)**
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11:25	**0 – unchartered**	**(15)**

Problem Statement and Requirements for 6LoWPAN Mesh Routing

(draft-dokaspar-6lowpan-routreq-06)

IETF-72 Dublin, Ireland

Tuesday, July 29, 2008

Eunsook Kim, Dominik Kaspar, Carles Gomez, Carsten Bormann

Last Meeting

- Result
  - Target document for 6LoWPAN routing requirement work

- Recharter text
  - "6LoWPAN Routing Requirements" will describe 6LoWPAN-specific requirements on routing protocols used in 6LoWPANs, addressing both the "route-over" and "mesh-under" approach.
  - This document will be created and owned by this working group but is expected to be reviewed by the ROLL WG.

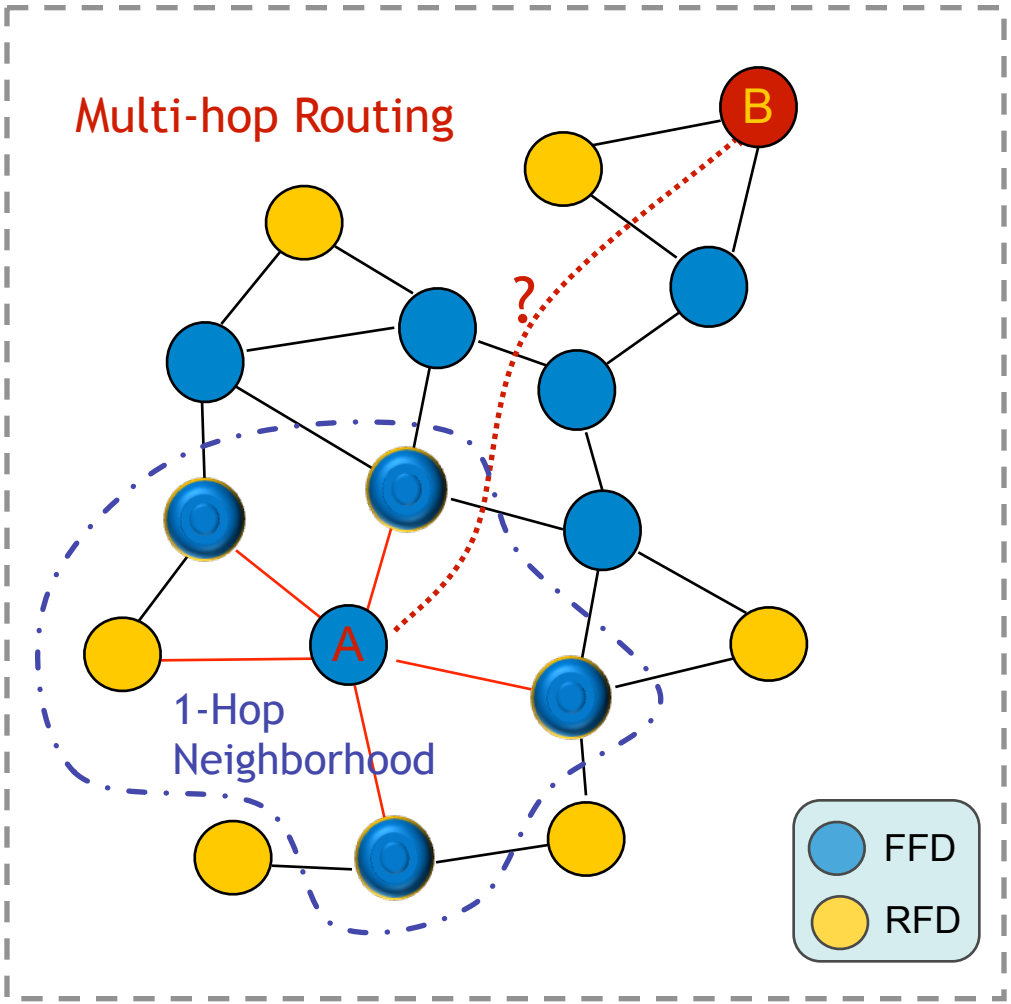
Draft Contents

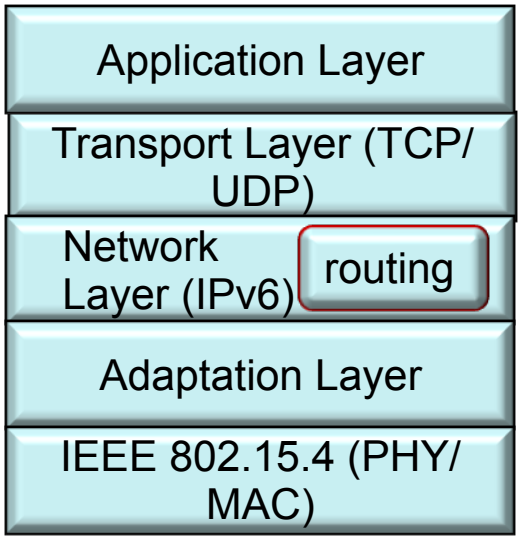
- Problem Statements
- Design space
- Scenario Considerations and Parameters for 6LoWPAN routing
- 6LoWPAN routing requirements
  - Routing Requirements depending on the 6LoWPAN Device Properties
  - Routing Requirements depending on Types of 6LoWPAN Applications
  - MAC-coupled Requirements
  - Mesh-under specific Requirements
  - Route-over specific Requirements
- Security Considerations

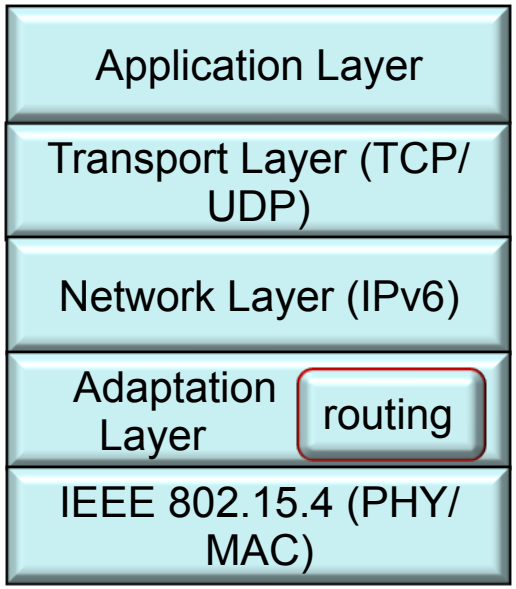
Problem Statements (-06)

- To meet rechartered text on 6lowpan routing requirements work:
  - Overall text modification to handle both mesh-under and route-over
  - More focusing on 6LoWPAN own features (inherited from IEEE 802.15.4) than those for general sensor networks

Design Space (-06)







Scenario considerations and 6LoWPAN routing parameters (-06)

- Update Parameters
  - Network Properties
    - Device Number, Density and Network Diameter
    - Connectivity
    - Dynamicity (include mobility)
    - Deployment
    - Spatial Distribution of Nodes and Gateways
    - Traffic Patterns, Topology and Applications
    - Quality of Service (QoS)
    - Security
  - Node Parameters
    - Processing Speed and Memory Size
    - Power Consumption and Power Source
    - Transmission Range
    - Traffic Pattern (high-loaded node-either source of packets or due to forwarding)
  - Link Parameters
    - Throughput
      - unslotted IEEE 802.15.4 2.4 GHz channel / 915 MHz / 868 MHz
    - Latency
      - unslotted IEEE 802.15.4 2.4 GHz channel / 915 MHz / 868 MHz

Routing Requirements (-06)

- depending on the 6LoWPAN Device Properties
  - Minimization of the required computational and algorithmical complexity
    - Typical low power sensor nodes have 8 or 16 bit microcontrollers.
    - They normally consume between 0.250 mA and 2.5 mA per MHz
  - a low routing state
    - Typical RAM size of 6LoWPAN nodes ranges between 2KB and 10KB, and program flash memory normally consists of 48KB to 128KB
  - Minimal(predictable) power consumption, both in the efficient use of control packet and also in the process of packet forwarding after route establishment
    - A example of an RF controller, CC1000, can transmit for approximately 4 days straight or receive for 9 days straight
  - Local change should not change global topology, and it shouldn't cause unjustified local cost.
  - Energy efficient Neighbor discovery

Routing Requirements (-06)

- depending on Types of 6LoWPAN Applications

→ has to be decided by application requirements

- support various traffic patterns; point-to-point, point-to-multipoint, and multipoint-to- point, while avoid relatively expensive multicast traffic (broadcast in Link)
- robust to dynamic loss caused by link failure or device unavailability
  - either in short-term (e.g. due to RSSI variation, interference variation, noise and asynchrony) ; or
  - in long-term (e.g. due to a depleted power source, hardware breakdown, operating system misbehavior, etc)
- Support of dynamically adaptive topologies and mobile nodes
- both scalability and minimality in terms of used system resources
  - Due to a lack of memory size and computational power, 6LoWPAN routing might limit forwarding entries to a small number

Routing Requirements (-04)

- MAC coupled requirements
  - secure delivery of control messages.
    - A minimal security level can be achieved by utilizing AES-based mechanism provided by IEEE 802.15.4.
  - No fragmentation of physical layer (PHY) frames by routing packets
    - Should support form of semantic fragmentation
  - MAY utilize a combination of the inputs provided by the MAC layer and other measures
    - Simple hop-count-only mechanisms may be inefficient in 6LoWPANs.
    - Routing metrics can be defined taking into account parameters like Link Delivery Ratio (LDR) which can be estimated using a Link Quality Indicator (LQI) from IEEE 802.15.4 and/or RSSI.
    - The metric to be used (and its goal) may depend on application and requirements.

Routing Requirements (-06)

- Mesh-under specific
  - Routing tables and neighbor lists MUST support 16-bit and 64-bit addresses
  - For neighbor discovery, 6LoWPAN devices SHOULD avoid sending "Hello" messages.
    - Instead, link-layer mechanisms (such as acknowledgments or beacon responses) MAY be utilized to keep track of active neighbors.
  - In case there are one or more alternative PAN coordinators, the coordinators MAY take the role of keeping track of node association and de-association within the 6LoWPAN
  - Alternative PAN coordinators, if any, MAY be a relay point of group-targeting message instead of using multicast (broadcast in the link layer)

Routing Requirements (-06)

- Route-over specific
  - In a multi-hop topology, 6LoWPAN network formation MUST support building up the IP network
    - RFD ??
  - IP multicast SHOULD be optimized, where it would require nodes to be awake

Next Step

- We focus on 6LoWPAN own requirements
- We cite ROLL docs on the related requirements
- WG feed-back on the document very much welcome
- Ready for WG draft?

72nd IETF: 6lowpan WG Agenda

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	1105 Use Cases	E Kim
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Design and Application Spaces for 6LoWPAN

(draft-ekim-6lowpan-scenarios-03)

IETF-72 Dublin

Tuesday, July 29, 2008

Eunsook Kim, Nicolas Chevrollier, Dominik Kaspar, JP Vasseur

Last Meeting

- Results
  - Baseline document for 6LoWPAN use-case
- Comments
  - Need to see 6LoWPAN applicability
- Charter text on the use-case work
  - Produce "Use Cases for 6LoWPAN" to define, for a small set of applications with sufficiently unique requirements, how 6LoWPANs can solve those requirements, and which protocols and configuration variants can be used for these scenarios.
  - The use cases will cover protocols for transport, application layer, discovery, configuration and commissioning.

Update (-03)

- 6LoWPAN applicability on:
  - Industrial Monitoring:
  - Structural Monitoring
  - Healthcare
- Not yet on
  - Connected Home
  - Vehicle Telematics
  - Agricultural Monitoring

e.g. 1) Storage monitoring

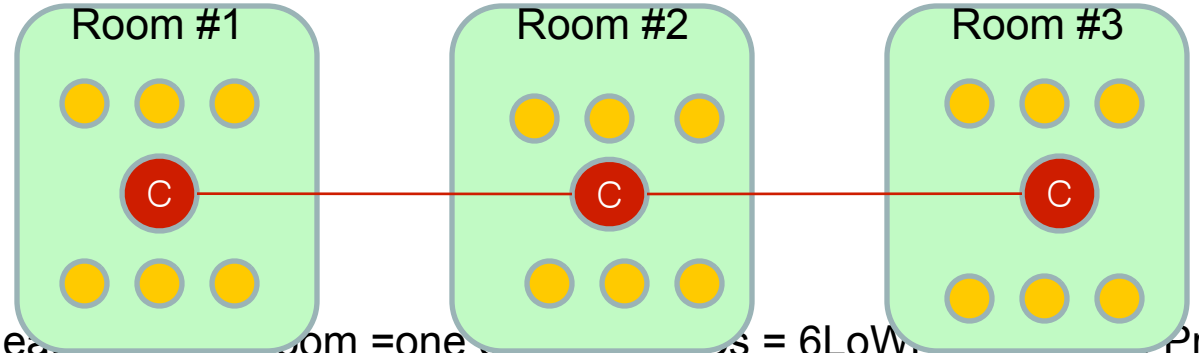
- Application Condition
  - In a hospital, maintenance of the right temperature in storage rooms is very critical. Red blood cells need to be stored at 2 to 6 degrees Celsius, Blood platelets at 20 to 24 C, and blood plasma below -18 C. For anti-cancer medicine, maintaining a humidity of 45% to 55% is required.
  - Storage rooms have temperature sensors and humidity sensors every 25m to 100m, based on the floor plan and the location of shelves, as indoor obstacles distort the radio signals. At each blood pack a sensor tag can be installed to track the temperature during delivery. A sensor node is installed in each container of a set of blood packs.

Storage Monitoring (cont'd)

- Dominant parameters
  - Deployment: pre-planned, manually attached
  - Mobility: no (except for the asset tracking case)
  - Network Size: medium to large size, high node density
  - Power Source: all battery-operated
  - Security Level:
    - business-critical.
    - Secure and reliable transmission must be guaranteed.
    - An extra key mechanism can be used
  - Routing:
    - single- to multi-hop.
    - Routing tables are merely changed after configuration, except in the asset tracking case.
    - Node failure or indoor obstacles will cause the changes.
  - Connectivity: always on for crucial processes, otherwise intermittent
  - Traffic Pattern: P2P (actuator control), MP2P (data collection)
  - Other Issues: Sensor network management

Storage Monitoring (cont'd)

- 6LoWPAN applicability
  - The simplest way: star topology and connect the storage rooms with one link.
  - Sensor nodes in the container: either FFDs or RFDs.

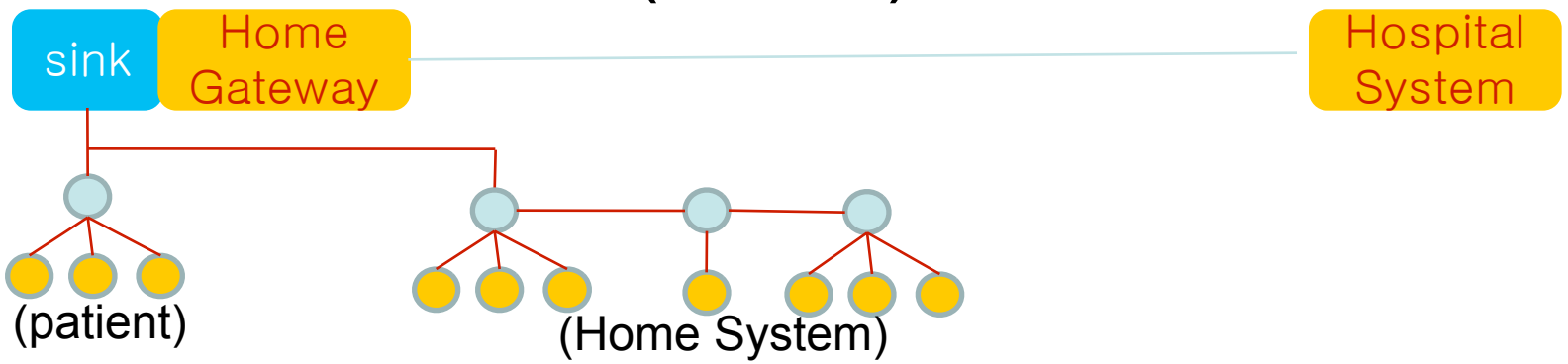


  - If each storage room =one 6LoWPAN, Cs = 6LoWPAN routers. Prefix allocation by 6LoWPAN routers. (ND = mesh-under or route-over: ongoing-works)
  - If the whole storage room == one 6lowpan, one of Cs = 6LoWPAN router
    - Most likely by manual setting for the default router.
  - Inside of the storage room, no need to have globally unique IPv6 addr.
  - containers moving case: globally unique addresses may need depending on the purpose of the system
  - If UDP (encapsulated in 6LoWPAN header or as it is) is used, secure transmission and security mechanism should be added
  - SNMP-like network management or 6LoWPAN Management, if developed.

e.g 2) Healthcare at Home by Tele-Assistance

- Dominant parameters
  - Deployment: pre-planned
  - Mobility: moderate (patient's mobility)
  - Power Source: hybrid
  - Security Level:
    - Data privacy and security must be provided.
    - Encryption is required.
    - Role based access control is required to be support by proper authentication mechanism
  - Routing:
    - multihop for homecare devices, star topology on patients body.
    - Multipath interference due to walls and obstacles at home must be considered.
  - Connectivity: always on
  - QoS: high level of support (life and death implication), role-based
  - Traffic Pattern: MP2P/P2MP (data collection), P2P (local diagnostic)
  - Other issues:
    - Plug-and-play configuration is required for mainly non-technical end-users.
    - Real-time data acquisition and analysis are important.
    - Efficient data management is needed for various devices which have different duty-cycles, and for role-based data control.
    - Reliability and robustness of the network are also essential.

Healthcare at Home by Tele-Assistance (cont'd)



- 6LoWPAN applicability
  - Home gateway -> default 6LoWPAN router
  - Each home system node
    - Plug&Play recommended, static network configuration (including Prefix, default router, key, etc) with consideration of signal distortion by obstacles.
    - Network formation: tree style, network management via the home gateway
    - Link-local address auto-configuration by RFC 4944
    - Multi-hop: mesh-header can be used for static forwarding, or routing function enabled FFDs for route-over (<- auto network configuration is needed)
  - The mobility of the patient's body area network: within home
    - patient body nodes → home system: no fast mobility support needed
  - Service access control

Questions and Future work

- Plan:
  - Enhancing 6LoWPAN applicability
- WG feed-back on the document very much welcome
- Ready for WG draft?

72nd IETF: 6lowpan WG Agenda

09:00	**Introduction, Status**	**Chairs (20)**
09:20	**1 – Bootstrapping/ND optimization**	**(65)**
10:25	**2 – HC**	**(20)**
10:45	**3 – Architecture**	**(10)**
10:55	**4 – Routing Requirements**	**(10)**
11:05	**5 – Use cases**	**(10)**
11:15	**6 – Security**	**(10)**
1115	Status of document	Chairs
11:25	**0 – unchartered**	**(15)**

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1125	Fragment recovery	P Thubert
1135	Extension headers	C Bormann

6LoWPAN Fragment recovery

P Thubert IETF 72

Need for fragment recovery

- Considering
  - that 6LoWPAN packets can be as large as 2K bytes
  - that a 802.15.4 frame with security will carry in the order of 80 bytes of effective payload,

=> An IPv6 packet might be fragmented into ~ 25 fragments at the 6LoWPAN shim layer

- This level of fragmentation is much higher than that traditionally experienced over the Internet with IPv4 fragments.
- At the same time, the use of radios increases the probability of transmission loss and Mesh-Under techniques compound that risk over multiple hops.

Other problems related to frags

- Hop by Hop recomposition
  - Should be avoided: latency and memory hit
- Multipath
  - Forwarding fragments over multipath multiplies the impact of an anomaly
- Recovery buffers Lifetime
  - Terminating device with limited capacity may have trouble maintaining buffers. How long?

Explicit Congestion Notification

- ECN in IPv6: Traffic Class bits 6-7

Binary	Keyword	References
00	Not-ECT (Not ECN-Capable Transport)	[RFC 3168]
01	ECT(1) (ECN-Capable Transport(1))	[RFC 3168]
10	ECT(0) (ECN-Capable Transport(0))	[RFC 3168]
11	CE (Congestion Experienced)	[RFC 3168]

  - Not compressed separately by 4944
  - Proposed addition to HC

- ECN Echo
  - Not an IP function (usually transport)
  - Thus provided by this draft

ECN use

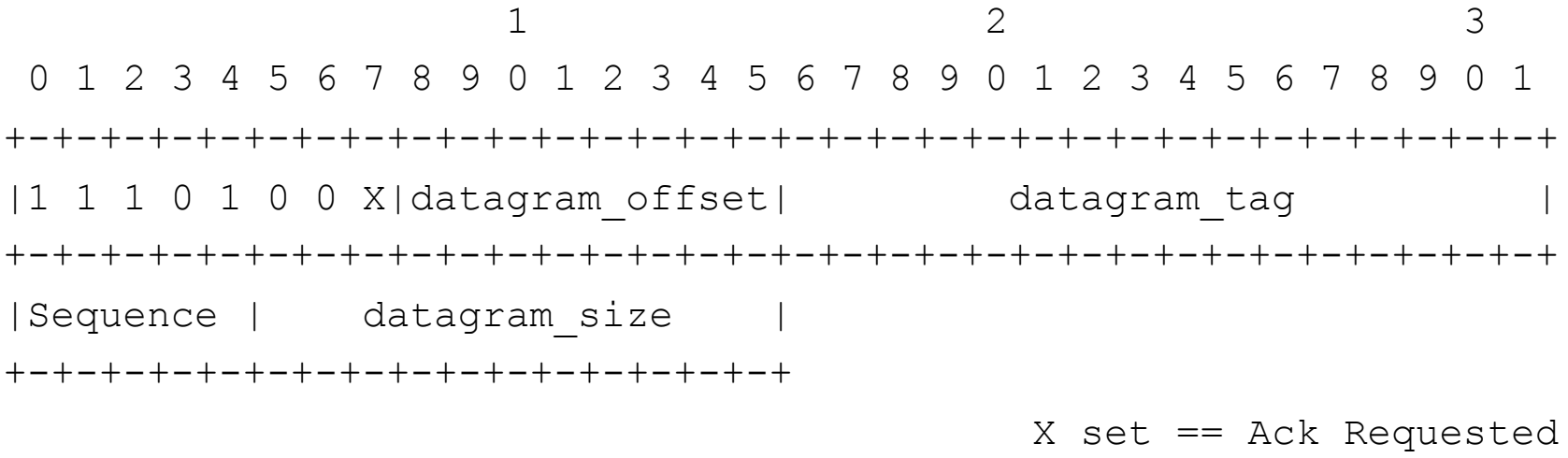
- Indicate Congestion in the LoWPAN
  - End to End effect on Transport
  - Required by ISA100.11a
  - Local Effect on Fragment flow control
- Early detection
  - Avoid Wasteful discard of packets
  - Conditions equivalent to RED

Fragment Recovery proposal

- 32 bits SAck Bitmap
- Variable window size for flow control
- Round Robin for multipath
- 4 new dispatch types

Pattern	Header Type	
11 101000	RFRAG	- Recoverable Fragment
11 101001	RFRAG-AR	- RFRAG with Ack Request
11 101010	RFRAG-ACK	- RFRAG Acknowledgement
11 101011	RFRAG-AEC	- RFRAG Ack with ECN echo

Recoverable Fragment Dispatch type and Header



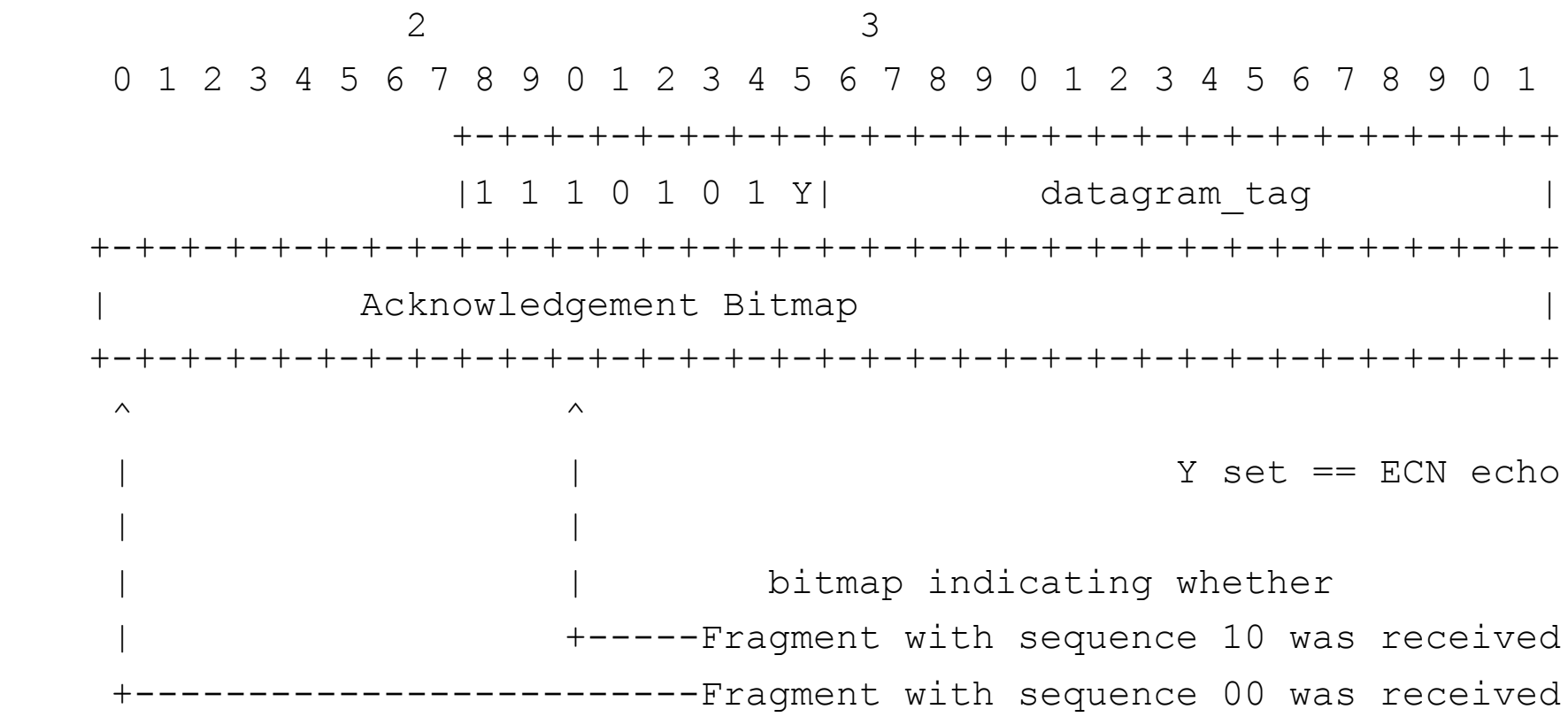
X (check) bit

When set, the sender requires an Acknowledgement from the receiver

Sequence

The sequence number of the fragment.
Fragments are numbered [0..N] where N is in [0..31].

Fragment Acknowledgement Dispatch type and Header



????? Questions ?????

Extension Headers

- **Problem: want to put random stuff into L2 packets**
- **Solution so far: Use NALP packets**
  - **i.e., no interoperability**
- **Proposed:**
  simple escape scheme for skipping extensions
- **Use up part of the unused fragmentation number space**
- **1 to 16 bytes per chunk**