IPv6 over Low power WPAN WG (6lowpan)

Chairs:
- Geoff Mulligan <geoff@mulligan.com>
- Carsten Bormann <cabo@tzi.org>

Mailing List:
- 6lowpan@ietf.org

Jabber:
- 6lowpan@jabber.ietf.org

http://6lowpan.tzi.org
• 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)
73rd IETF: 6lowpan WG Agenda

09:00  Introduction, Status  Chairs (10)
09:00  5 – Use cases (00)
09:10  4 – Routing Requirements  EK (30)
09:40  2 – HC  JH (30)
10:10  1 – Bootstrapping/ND optimization  ZS (50)
00:00  3 – Architecture (00)
00:00  6 – Security (00)
11:00  0 – wither 6lowpan  Chairs (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)
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# 73rd IETF: 6lowpan WG Agenda

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http://6lowpan.tzi.org  
6lowpan@IETF73, 2008-11-18
Milestones (from WG charter page)

Document submissions to IESG:

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone Description</th>
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<tbody>
<tr>
<td>Aug 2008</td>
<td>x 2 Improved Header Compression (PS)</td>
</tr>
<tr>
<td>Aug 2008</td>
<td>// 6 Security Analysis (Info)</td>
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<tr>
<td>Sep 2008</td>
<td>// 3 Architecture (Info)</td>
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<td>Sep 2008</td>
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<tr>
<td>Nov 2008</td>
<td>x 1 Bootstrapping and ND Optimizns (PS)</td>
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<td>Dec 2008</td>
<td>x 5 Use Cases (Info)</td>
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Also: running documents for implementers, interop
# 73rd IETF: 6lowpan WG Agenda

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Design and Application Spaces for 6LoWPAN
(draft-ietf-6lowpan-usecase-00)
(draft-ietf-6lowpan-usecase-01)

IETF-73 Minneapolis
Tuesday, November 18, 2008

Eunsook Kim, Nicolas Chevrollier, Dominik Kaspar, JP Vasseur
Draft Status

• WG draft (-00 was posted in October)
• Changes (-00 → -01)
  – Addition of 6lowpan applicability for 2 use-cases
• To do
  – 6lowpan applicability is still missing at Home automation
Questions and Future work

• Plan:
  – Want to be ready for WGLC by the next meeting
• WG feed-back on the document very much welcome
### 73rd IETF: 6lowpan WG Agenda

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Problem Statement and Requirements for 6LoWPAN Routing
(draft-dokaspar-6lowpan-routreq-07)
(draft-dokaspar-6lowpan-routreq-08)

IETF-73 Minneapolis
Tuesday, Nov. 18, 2008

Eunsook Kim, Dominik Kaspar, Carles Gomez, Carsten Bormann
Draft status

- Status
  - Target document for 6LoWPAN routing requirement work

- Charter 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.

- This work was intended to be done at Sep. 2008
Problem to solve

IETF-73– 6lowpan

Transport Layer (TCP/UDP)
Network Layer (IPv6)
Adaptation Layer
IEEE 802.15.4 (PHY/MAC)

Application Layer
Transport Layer (TCP/UDP)
Network Layer (IPv6)
Adaptation Layer
IEEE 802.15.4 (PHY/MAC)

Multi-hop Routing

1-Hop Neighborhood

FFD
RFD

IETF-73– 6lowpan
Major Changes (06→07→08)

- Restructuring
- Improvement with details and examples through the whole text
- 3 requirements are added
  - Probability of delivery
  - Latency requirement
  - Link asymmetry
- 2 requirements are deleted
Routing Requirements (-08)

- Support of 6LoWPAN Device Properties
  - [R01] Code size and routing state
    - code size considering typical node memory size
    - routing table up to 32 entries
  - [R02] Power consumption due to routing messages and routing of data
    - Some example value, transmission consumes about 20 to 30mW, reception consumes about 15 to 20mW.
Routing Requirements (-08)

- **Support of 6LoWPAN link properties**
  - [R03] fragmentation from routing control messages
    - Max of 6lowpan frame is 81 octets.
    - Use of semantic fragmentation and/or algorithm that can work on small increments of routing info.
  - [R04] Probability of Packet delivery
    - max no of transmission attempts in reliable mode
  - [R05] Latency
    - To meet specific latency requirement for applications, 6lowpan link latency can be considered (e.g., 2.4 GHz channel of 802.15.4 is between 2.4ms and 6.02ms (64bit addr., unreliable mode)
      - Latency can be used for path selection
  - [R06] Robustness to dynamic loss
  - [R07] Link asymmetry
Routing Requirements (-08)

- Support of 6LoWPAN Network characteristics
  - [R08] Consideration of sleeping nodes
    - Feedback from the lower layer may be considered to enhance the power-awareness of 6lowpan routing protocols
  - [R09] Routing metrics
    - Several input can be used including LQI, LDR, RSSI, etc.
    - the discussion how the parameters can be used is included
  - [R10] Scalability and minimality
    - Scale from $2 \sim 10^x$ to nodes, with limited routing table
  - [R11] Routing repair
    - To avoid premature depletion, even in case that impairs other reqt.
  - [R12] Dynamic topology
    - Consideration
      - Mobile nodes changing their location inside a 6LoWPAN
      - Movement of a 6loWPAN wrt other (inter)connected 6LoWPANs
      - Nodes permanently joining or leaving the 6LoWPAN
      - inform the coordinator about intention to disassociate, when nodes leaving the network
  - [R13] traffic pattern
    - p2p, p2m, m2p
Routing Requirements (-08)

- Support of Security
  - [R14] Secure delivery
    - Minimum: IEEE 802.15.4 AES-based security mechanisms (up to 21 additional bytes)

- Support of mesh forwarding
  - [R15] support of 16-bit and 64-bit addresses
  - [R16] Avoidance of "Hello" messages
    - Use of layer 2 acknowledgement

- Use of nodes with coordinator role
  - [R17] the coordinators MAY take the role of keeping track of node association and de-association within the 6LoWPAN
  - [R18] the coordinators MAY be a relay point of group-targeting message
Next Steps

- We focus on 6LoWPAN’s own requirements
- WG FEED-BACK on the document TEXT very much welcome
- Ready for WG draft?
- We intend this work to be done within this year
## 73rd IETF: 6lowpan WG Agenda

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Compression Format for IPv6 Datagrams in 6LoWPAN Networks
(draft-ietf-6lowpan-hc-03.txt)

Jonathan Hui
Pascal Thubert

6LoWPAN WG Meeting
73rd IETF Meeting
Minneapolis, Minnesota
Background

- Improved header compression for:
  - Global Addresses
  - Multicast Addresses
  - Traffic Class and Flow Label
  - Hop Limit
  - Arbitrary Next Headers

- Maintain properties of RFC4944 compression
  - Stateless compression for link-local addresses
  - Context-based compression for global addresses
Changes from draft-00

- **IP Header Compression**
  - Traffic Class and Flow Label compression
  - Multicast address compression
  - Unspecified Address compression
  - Support for up to 16 contexts

- **UDP Header Compression**
  - Port compression alignment
  - Checksum compression
IPv6 Header Compression

<table>
<thead>
<tr>
<th>Field</th>
<th>Bits</th>
<th>Description</th>
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<tbody>
<tr>
<td>TF</td>
<td>2</td>
<td>Traffic Class and Flow Label</td>
</tr>
<tr>
<td>NH</td>
<td>1</td>
<td>Next Header</td>
</tr>
<tr>
<td>HLIM</td>
<td>2</td>
<td>Hop Limit</td>
</tr>
<tr>
<td>CID</td>
<td>1</td>
<td>Context Identifier Extension</td>
</tr>
<tr>
<td>SAC</td>
<td>1</td>
<td>Source Address Context</td>
</tr>
<tr>
<td>SAM</td>
<td>2</td>
<td>Source Address Mode</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
<td>Multicast Address Compression</td>
</tr>
<tr>
<td>DAC</td>
<td>1</td>
<td>Destination Address Context</td>
</tr>
<tr>
<td>DAM</td>
<td>2</td>
<td>Destination Address Mode</td>
</tr>
</tbody>
</table>
Traffic Class & Flow Label

TF = 0

ECN | DSCP | rsv | Flow Label

TF = 1

ECN | rsv | Flow Label

TF = 2

ECN | DSCP

TF = 3

Traffic Class and Flow Label elided.
## Hop Limit

<table>
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<tr>
<th></th>
<th></th>
<th></th>
<th>TF</th>
<th>NH</th>
<th>HLIM</th>
<th>CID</th>
<th>SAC</th>
<th>SAM</th>
<th>M</th>
<th>DAC</th>
<th>DAM</th>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

- **0**: Hop Limit carried in-line.
- **1**: Hop Limit = 1 and elided.
- **2**: Hop Limit = 64 and elided.
- **3**: Hop Limit = 255 and elided.
# Context Identifier Extension

**CID = 0**: Default context

**CID = 1**: Context identifier extension

- Number of contexts actually used is out of scope.
Source Address

SAC = 0: Stateless compression for link-local communication

- SAM = 0: Completely elided (Unspecified Address)
- SAM = 1: 64-bit IID
- SAM = 2: 16-bit
- SAM = 3: Completely elided (IID from Lower Layers)

SAC = 1: Context-based compression

- SAM = 0: Full 128-bit Address
- SAM = 1: 64-bit IID
- SAM = 2: 16-bit
- SAM = 3: Completely elided (IID from Lower Layers)
Destination Unicast Address

M = 0 (Unicast Address Compression)
DAC = 0: Stateless compression for link-local communication
DAC = 1: Context-based compression

SAM = 0  Full 128-bit Address
SAM = 1  64-bit IID
SAM = 2  16-bit
SAM = 3  Completely elided (IID from Lower Layers)
M = 1 (Multicast Address Compression)
DAC = 0: Stateless compression

SAM = 0
Flags | Scope | Right-Most 40 bits of Group Identifier | 6 bytes

FFXX::00XX:XXXX:XXXX
Solicited Node and Node Information Queries

SAM = 1
Flags | Scope | Right-Most 24 bits of Group Identifier | 4 bytes

FFXX::XX:XXXX
Longer well-known addresses (all-dhcp-servers FF05::1:3)

SAM = 2
Scope | Group ID (12 bits) | 2 bytes (Flags = 0)

FF0X::0XXX
Variable scoped multicast addresses

SAM = 3
GID (8 bits) | 1 byte (Flags = 0, Scope = 2)

FF02::00XX
Most common link-local cases (link-local all-nodes FF02::1)
**Destination Multicast Address**

M = 1 (Multicast Address Compression)
DAC = 1: Context-based compression

SAM = 0  Full 128-bit address in-line

SAM = 1

<table>
<thead>
<tr>
<th>Flags</th>
<th>Scope</th>
<th>RIID</th>
<th>32-bit Group Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFXX:RIID:[plen][prefix]:XXXX:XXXX</td>
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</tbody>
</table>

Unicast-Prefix-based Multicast Addresses

SAM = 2  Reserved

SAM = 3  Reserved
### UDP

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>I</td>
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<td>I</td>
<td>I</td>
<td>0</td>
<td>C</td>
<td>P</td>
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#### Checksum Compression

<table>
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<th>0</th>
<th>Checksum carried in-line.</th>
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<tbody>
<tr>
<td>1</td>
<td>Checksum elided with higher-layer end-to-end integrity checks.</td>
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#### Port Compression

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<th>Source Port</th>
<th>Destination Port</th>
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<tbody>
<tr>
<td>0</td>
<td>0xFOXX</td>
<td>0xFOXX</td>
</tr>
<tr>
<td>P = 1</td>
<td>Source Port</td>
<td>Destination Port</td>
</tr>
<tr>
<td></td>
<td>0xFOXX</td>
<td></td>
</tr>
<tr>
<td>P = 2</td>
<td>Source Port</td>
<td>Destination Port</td>
</tr>
<tr>
<td></td>
<td>0xFOXX</td>
<td></td>
</tr>
<tr>
<td>P = 3</td>
<td>Source Port</td>
<td>Destination Port</td>
</tr>
<tr>
<td></td>
<td>0xFOBX</td>
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Summary of Changes

- **IP Header Compression**
  - Traffic Class and Flow Label compression
  - Multicast address compression
  - Unspecified Address compression
  - Support for up to 16 contexts

- **UDP Header Compression**
  - Port compression alignment
  - Checksum compression
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draft-shelby-6lowpan-nd-01

Authors:
Zach Shelby (ed.)
Jonathan Hui
Pascal Thubert
Samita Chakrabarti
Erik Nordmark
Background

• Design team formed in Dublin
• Based on ideas from 5 ND related drafts:
  • draft-chakrabarti-6lowpan-ipv6-nd-05
  • draft-thubert-6lowpan-backbone-router-01
  • draft-hui-6lowpan-nd-00
  • draft-nordmark-6lowpan-reg-00
  • draft-bormann-6lowpan-cbhc-00
• Note: -01 posted yesterday
Main goals

- Bootstrapping on a lowpan
- Router and prefix information dissemination
- DAD or NS avoiding multicast
- Stateless address assignment
- Enabling ND over a lowpan or extended lowpan
  - Wireless link model, frequent topology change
- Mesh-under and route-over agnostic
Architecture - Route Over

Subnet-local Scope

Link-local Scope

h: Host
r: Router

h h h
h r r h
h r h r
h r
r h
Architecture - Mesh-under

m: Mesh node

Subnet-local Scope

Link-local Scope
Architecture – Single lowpan

Subnet-local Scope

Backhaul link

Edge router

o: Any node
Architecture – Extended lowpan

Subnet-local Scope

Link-local Scope

Extended LoWPAN

0 Host

Link-local Scope

Subnet-local Scope
The solution

• Simplify and reduce IPv6 ND [RFC4861]

• 6lowpan prefix information dissemination
  • Standard RAs with extra flag (optional)

• Bootstrapping with ND techniques

• Router Registration/Confirmation message (optional)
  • ERs act as whiteboards for their LoWPAN
  • Can be used to get a stateless address

• Support for DAD over extended LoWPANs and proxying across the ER (optional)
  • Can be achieved with ND-Proxy or a routing protocol
Whiteboard model

A whiteboard binding entry has the following fields:

- Host Interface Identifier
- IPv6 Address
- Lifetime

Bindings are soft

- Must be refreshed
- Can be moved between ERs
Basic features

Whiteboard binding for all lowpan addresses

DAD and NS performed by the ER

Nodes register with an ER

RA Dissemination
Optional features

Subnet over the extended lowpan + backbone

Address assignment

Extended LoWPAN
Message exchanges

Node                  (Edge) Router

|                       | <-------- Router Advertisement --------> |
|                       | <-------- Router Registration --------> |
|                       | <-------- Router Confirmation --------> |

Node                  Router (relay)                  Edge Router

|                       | ----- RR ----- | ----- RR ----- |
|                       | ----- RR ----- | ----- RR ----- |
|                       | <----- RC ---- | <----- RC ---- |
RA dissemination

- ERs initiate the dissemination of network information
- RAs are sent periodically by default
- Optionally trickle could be applied (TBD)
- Routers then disseminate forward
- RAs include
  - Default prefix and HC address contexts (option for each)
  - Multihop information option with sequence number
    - To indicate freshness of information
    - Full list of contexts needs to be sent only rarely
# RA message

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
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<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Checksum</th>
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<tr>
<td>Cur Hop Limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Router Lifetime</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reachable Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrans Timer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options ...</td>
<td></td>
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</tr>
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</table>

**M** - Used to indicate that stateless address assignment used.

**E** - “Edge Router” flag indicating that the routing sending the RA is an Edge Router.

**NOTE:** Under discussion to replace E flag with RFC4191 Router Preference flags for -02 e.g. With ER = high, Router = medium, Limited Router? = low
RA options

6LoWPAN Prefix Information Option (A new option!)

CID – Context Identifier for use in 6LoWPAN HC compression.

Multihop Information Option
RR/RC message

<table>
<thead>
<tr>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</th>
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<tr>
<td>+----------------------------------------------------------------</td>
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<td>+----------------------------------------------------------------</td>
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<tr>
<td></td>
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<tr>
<td>+----------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| | Binding option(s)...
| +----------------------------------------------------------------|

**TID** - Transaction ID for matching confirmations.

**P** - Primary flag for using an ER as primary. For use with secondary registrations.

**X** - Proxy flag in a confirmation to indicate ND-Proxy in use.

**NOTE**: May not be necessary, could be removed.

**HII** - Has been suggested to rename HII to Owner Interface Identifier
RR/RC options

Address Option

+ -+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |    Status     |
+ -+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

D | A | R |        Reserved         |         IPv6 Address        ...

P/S - Prefix and suffix compression fields.

D - Allow duplicates flag.

A - Address assignment flag.

R - Remove address flag.

Source link-layer address option [RFC4861, RFC4944]

Target link-layer address option [RFC4861, RFC4944]
Changes since -00

- Message structure simplified
  - RR/RC message pair, no separate relay messages
  - Removed Identity Option and 6LoWPAN Addr Opt
  - Address Options under the RR/RC
- Clarified that address assignment is stateless
- Added Ad-hoc LoWPAN and Message Example sections
  - Just placeholders for now
- Editing improvements and better clarity
Open issues with -01

- Replacement of RA E flag with RFC4191
- Trickle algorithm description
- Routing algorithm as ND-Proxy alternative
- Is X flag needed in RC?
- Description of primary/secondary bindings?
- Is an index needed in the Address Option?
- Editorial issues
  - Not all subsections complete
  - Minor editing and consistency
Moving to -02

- Including additional WG feedback
- Message structure stable
- General editorial work
  - Finishing all subsections
  - Cross-referencing with draft-ietf-6lowpan-hc
  - Minor editing and consistency
- Aiming at -02: within 2-3 weeks
Implementation

- From -01 on, encouraging implementation work
  - Many are starting HC implementation work
  - Good time to start ND implementation as well
- We already have an implementation
  - Implementation close to this -01 draft
  - Java simulator also developed for large networks
  - Initial results from testing & simulation good
- If you are working on implementation, let us know
Accept draft-shelby-6lowpan-nd-01 as a WG document?
# 73rd IETF: 6lowpan WG Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
<th>Duration</th>
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<td>Chairs (10)</td>
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<tr>
<td>00:00</td>
<td>5 – Use cases</td>
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<td>(00)</td>
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<tr>
<td>09:10</td>
<td>4 – Routing Requirements</td>
<td>EK</td>
<td>(30)</td>
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<tr>
<td>09:40</td>
<td>2 – HC</td>
<td>JH</td>
<td>(30)</td>
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<tr>
<td>10:10</td>
<td>1 – Bootstrapping/ND optimization</td>
<td>ZS</td>
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<tr>
<td>00:00</td>
<td>3 – Architecture</td>
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<td>(00)</td>
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<td>00:00</td>
<td>6 – Security</td>
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<td>(00)</td>
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<tr>
<td>11:00</td>
<td>0 – wither 6lowpan</td>
<td>Chairs</td>
<td>(15)</td>
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Interesting results nobody noticed
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  - 64 is a good default?
  - routinely decrementing by more than one?
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- RFC 4294 vs. **we don’t do no ____ multicast**
# Milestones (from WG charter page)

Document submissions to IESG:

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone Description</th>
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<tbody>
<tr>
<td>Aug 2008</td>
<td>x 2 Improved Header Compression (PS)</td>
</tr>
<tr>
<td>Aug 2008</td>
<td>// 6 Security Analysis (Info)</td>
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<tr>
<td>Sep 2008</td>
<td>// 3 Architecture (Info)</td>
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<tr>
<td>Sep 2008</td>
<td>x 4 Routing Requirements (Info)</td>
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<tr>
<td>Nov 2008</td>
<td>x 1 Bootstrapping and ND Optimizns (PS)</td>
</tr>
<tr>
<td>Dec 2008</td>
<td>x 5 Use Cases (Info)</td>
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Also: running documents for implementers, interop
Architecture

- Do we distribute/spread the document between
  - ND Optimizations (link model)
  - Routing Requirements
  - Use Cases
Security

• Is it all about protecting the network?
  ▪ AES hop-by-hop security?
  ▪ Do we have to express preference for some 15.4 AES modes?
• Is manually commissioning keys enough?
So, is there anything left to do?
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- ... and anybody there willing to commit to doing the work?
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- ... and anybody there willing to commit to doing the work?

- (We can always do a MIB :-)