Routing Protocol Comparison for 6LoWPAN

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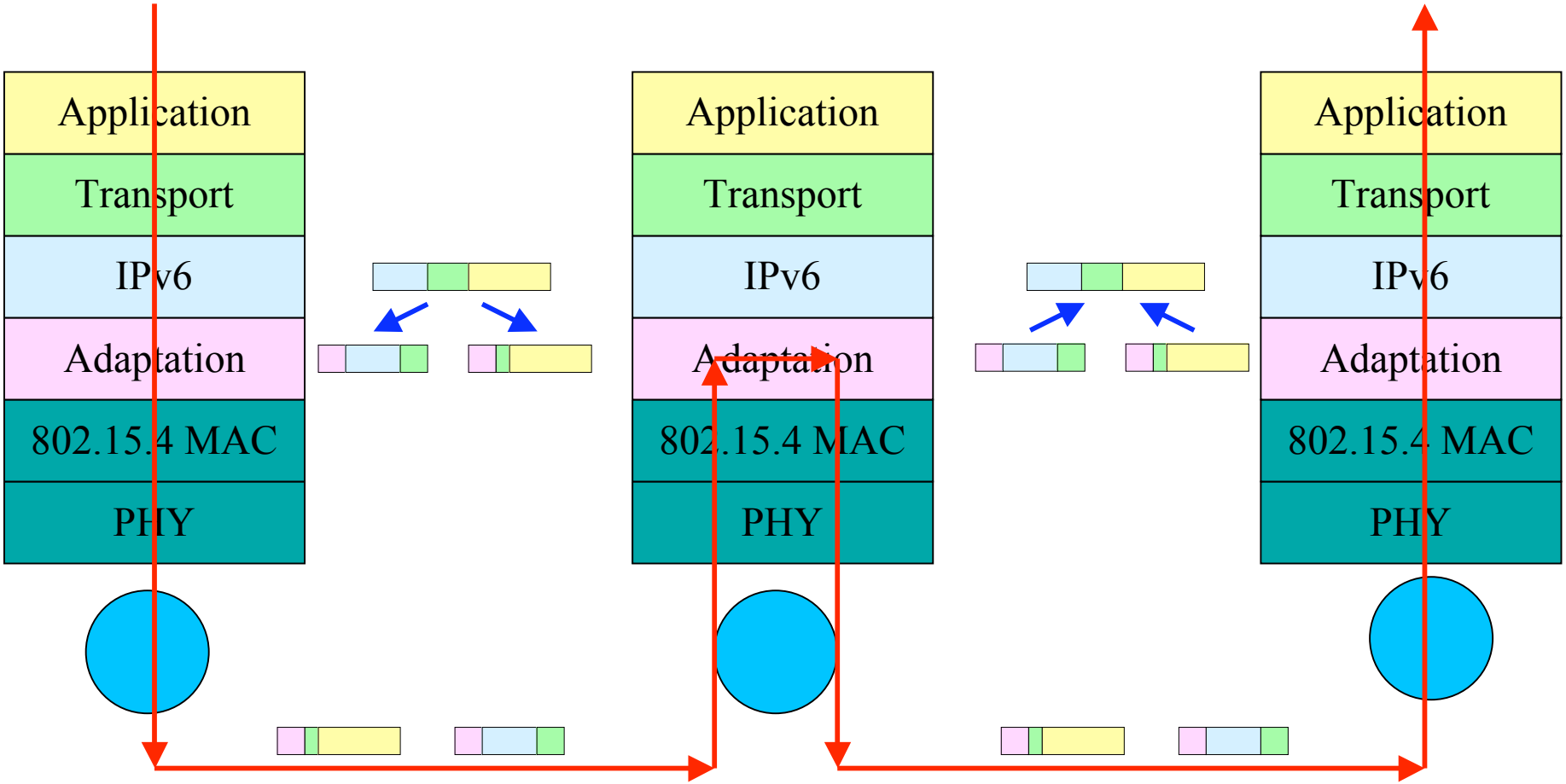
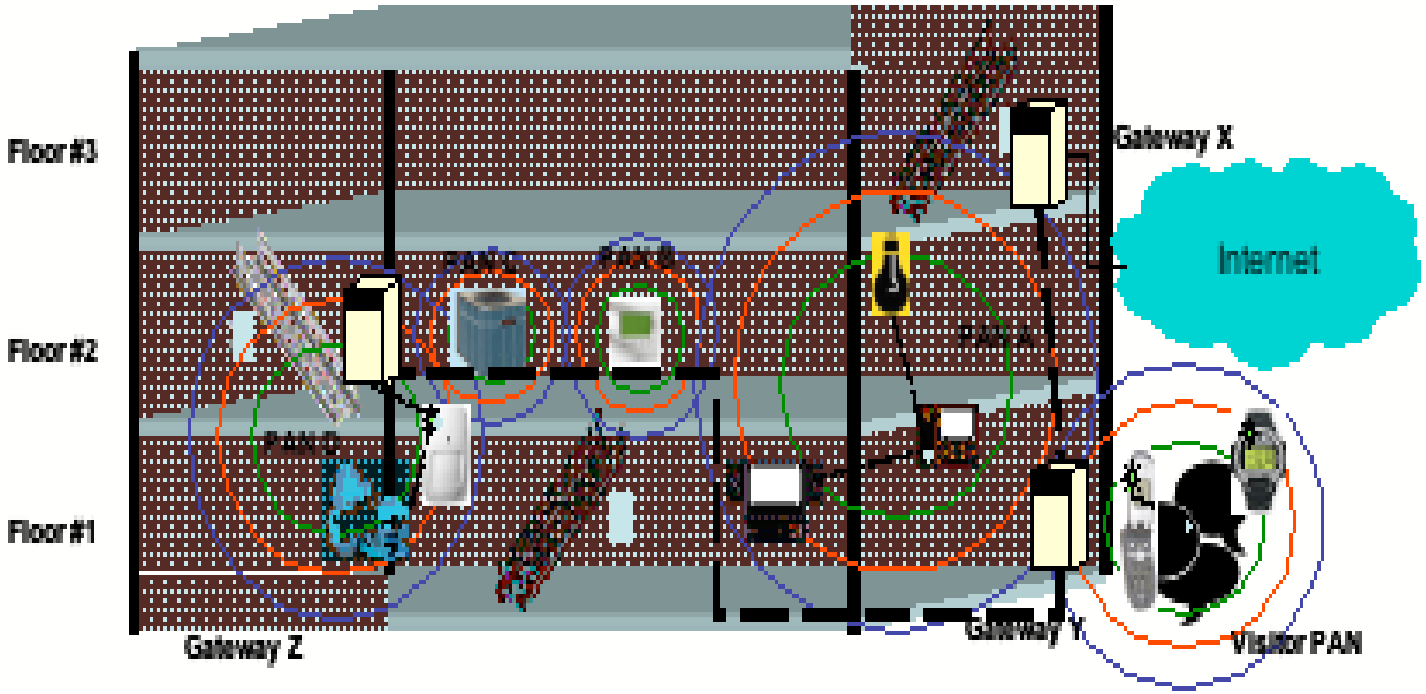
- Comparison of routing protocols for 6lowpan
- Interoperability Issues with external IPv6 networks

Mesh Routing underneath to IPv6 Layer



Inter-PAN Routing Protocol

- LOAD is an Interworking Routing Protocol for a PAN of Multi ple PANs
- Furthermore, LOAD supports for Internet of PANS (i.e. Sea mless All IP-based Wired Networks and Wireless PANs)



6LoWPAN Ad Hoc On-Demand Distance Vector Routing (LOAD)

Ki-Hyung Kim (Ajou Univ),
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G. Montenegro (Microsoft Corporation)
S. Yoo (Ajou Univ)

(draft-daniel-6lowpan-load-adhoc-routing-01.txt)

Introduction

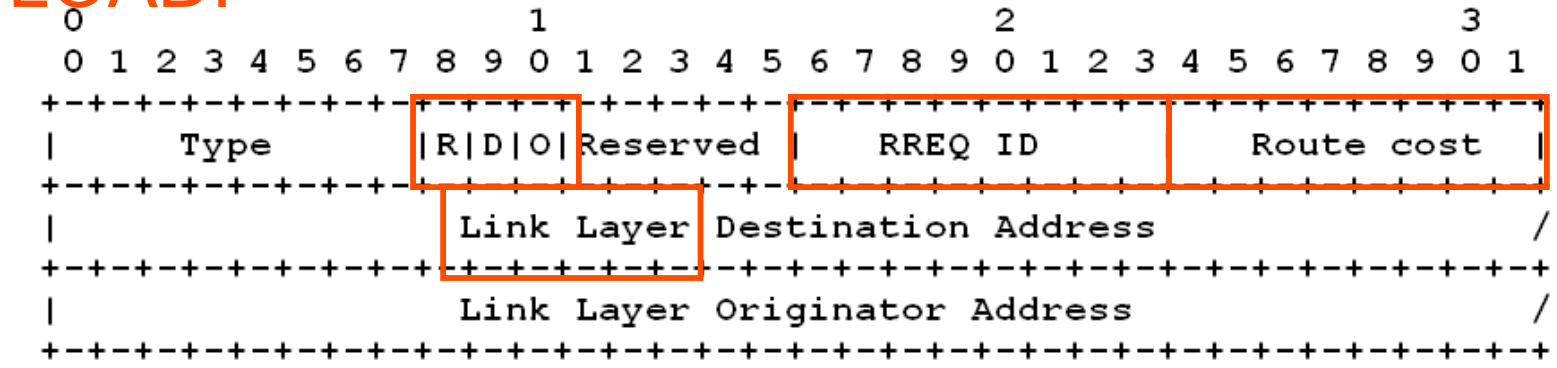
- 6LoWPAN Ad hoc Routing Protocol (LOAD) i s a simplified on-demand routing protocol ba sed on AODV[RFC3561] for 6LoWPAN
- Change-Log
  - This draft (01) is the merged version of
  - draft-daniel-6lowpan-load-adhoc-routing-00.txt
  - draft-montenegro-lowpan-aodv-00.txt

Main Features of LOAD

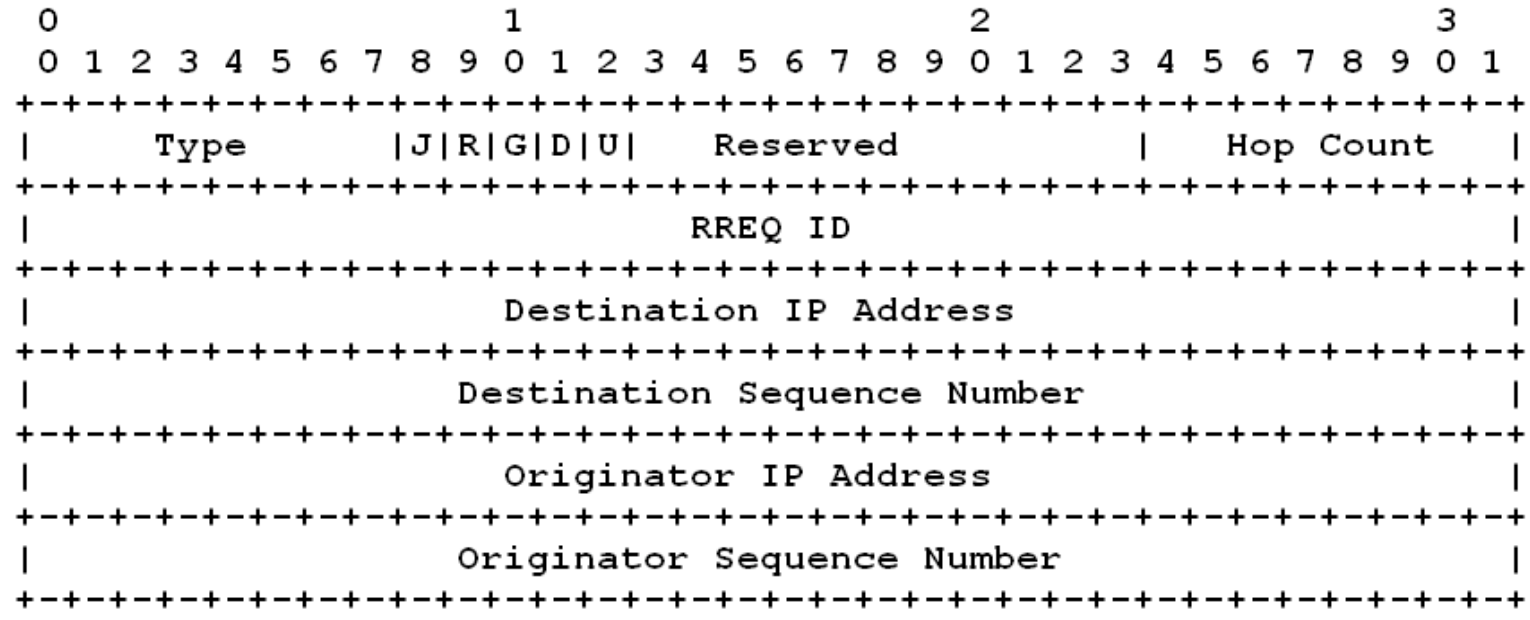
- Use EUI-64 or 16 bit addresses
- Use broadcast in the route discovery
- Do not use the destination sequence number
- Only destination Replies to RREQ by RREP
- Do not use the local repair
- Report back to the originator by RERR upon a link break
  - Do not maintain the precursorlist
  - Send RERR only to the originator of the data which caused the link break
- Use the route cost by utilizing the LQI of the 6LoWPAN PH Y
  - Allow multiple schemes such as hop counts, aggregated LQI values, and minimum LQI value along a route
- Use the Acknowledged transmission option for keeping the connectivity of a route (Does not use HELLO)
- Maintains two tables: Route Request table, Routing table

Route Request (RREQ) Message

LOAD:

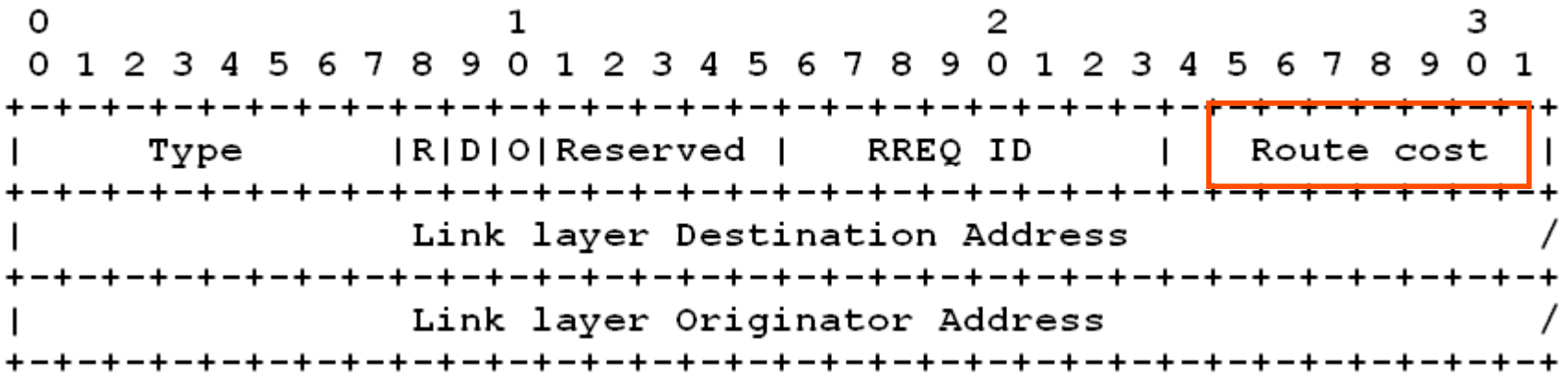


AODV:

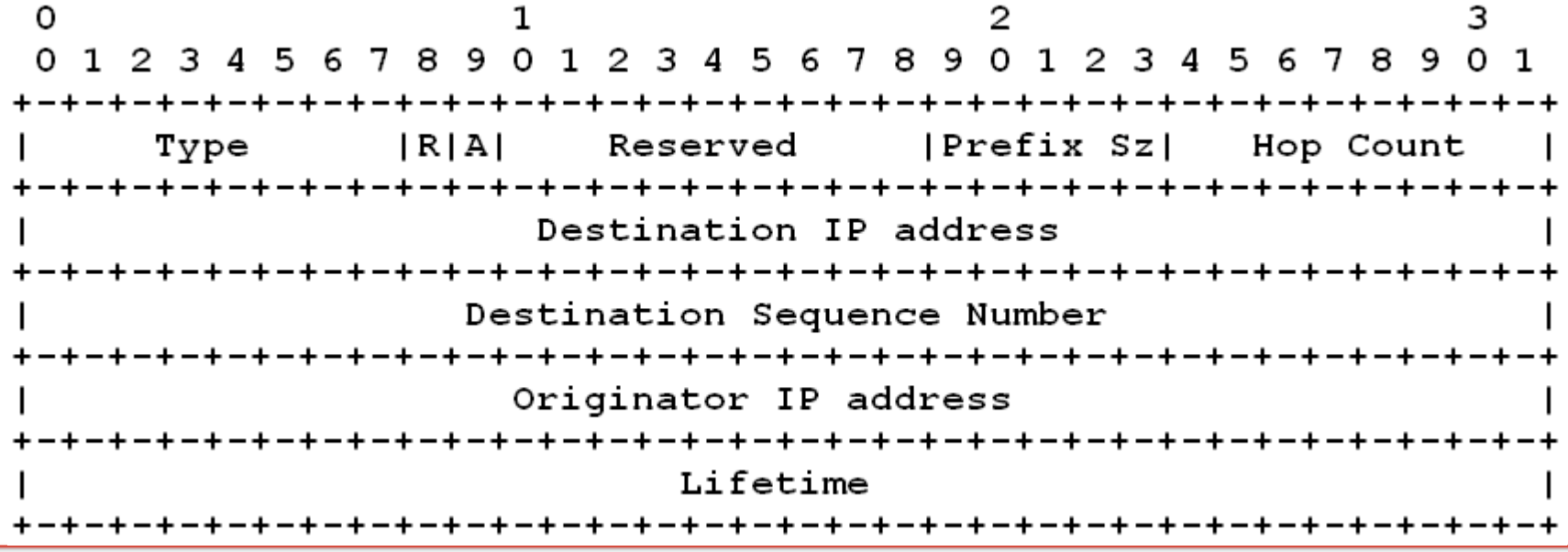


Route Reply (RREP) Message

LOAD:

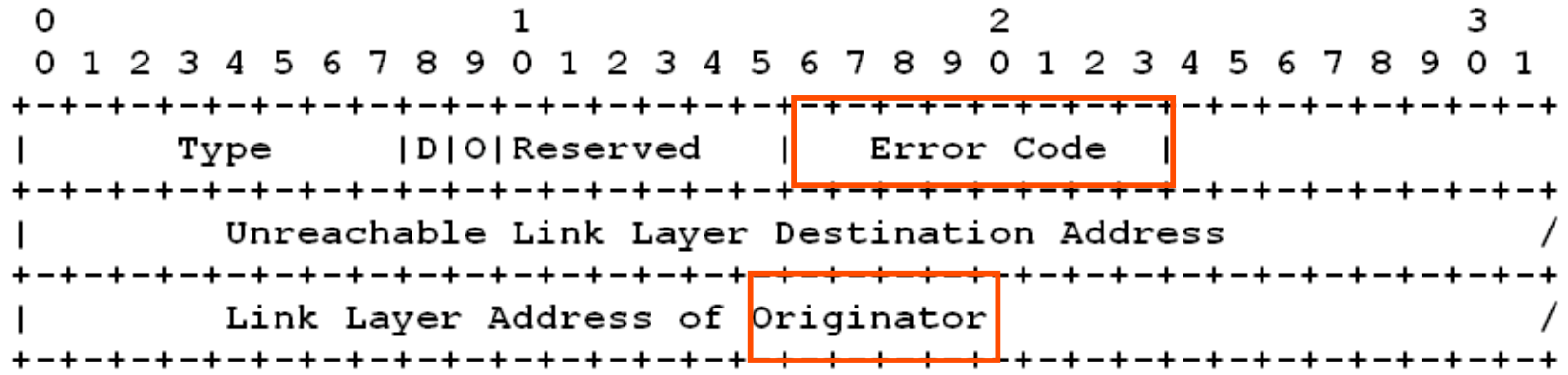


AODV:

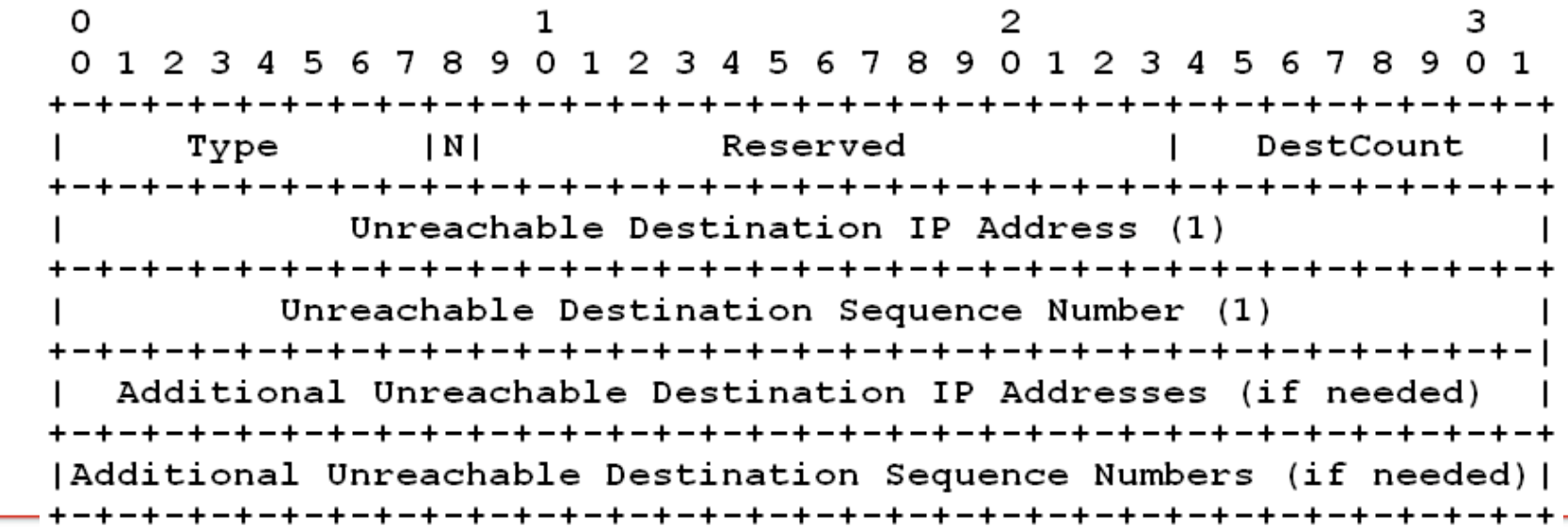


Route Error (RERR) Message

LOAD:



AODV:



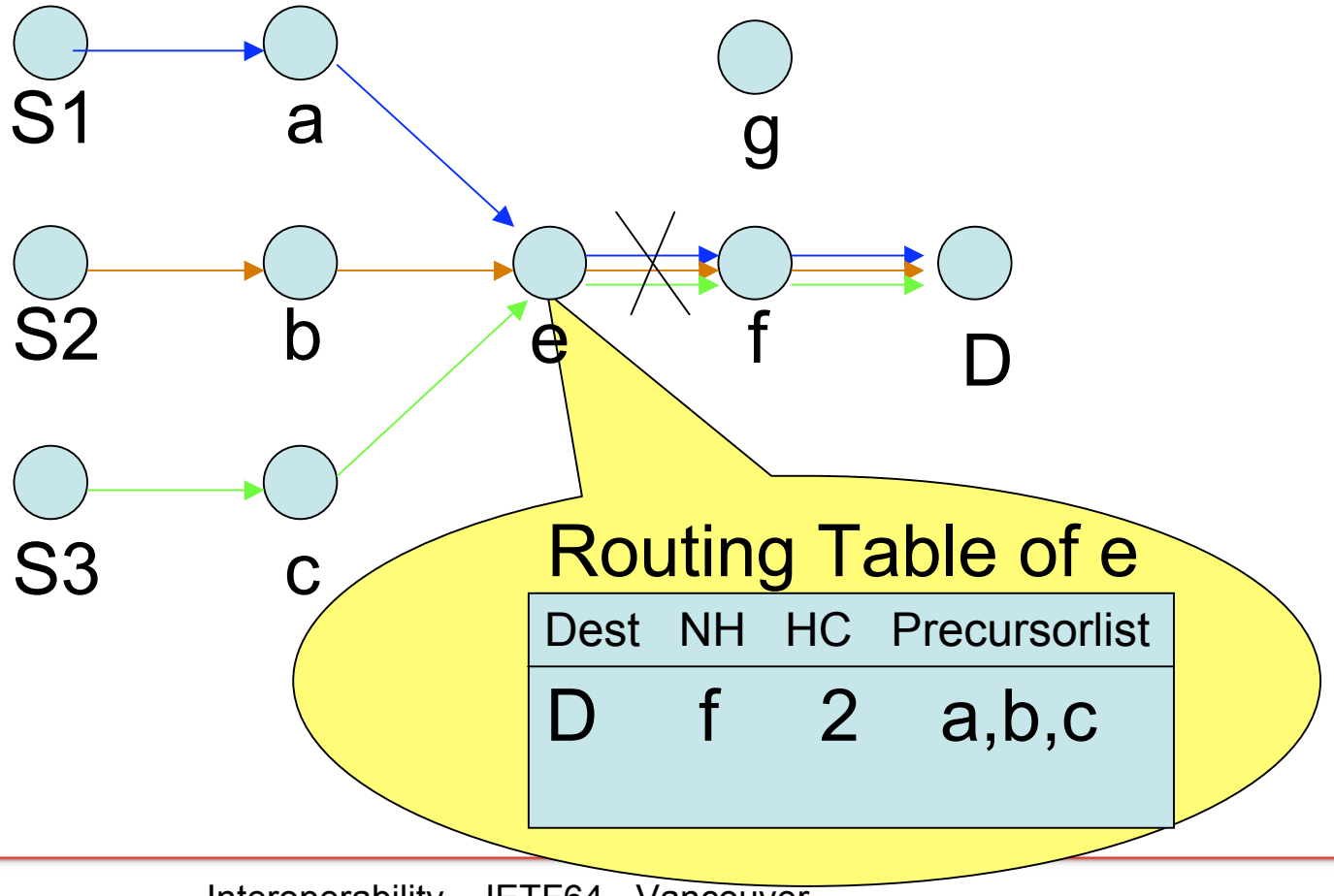
Route Error Reporting Schemes

RERR Back Propagation

- AODV
  - Utilize Precursorlist to reach the originators
- LOAD
  - Does not use precursorlist -- to reduce the overhead of RERR processing
  - Use the originator address of data packets
    - If the future revision of the format document allows the source ad dress for multihop packets
    - Maintain symmetric forward and backward route on intermediate nodes
    - Does not allow local repair
  - Unicast one-hop back propagation when there is no way to know the route to the originator

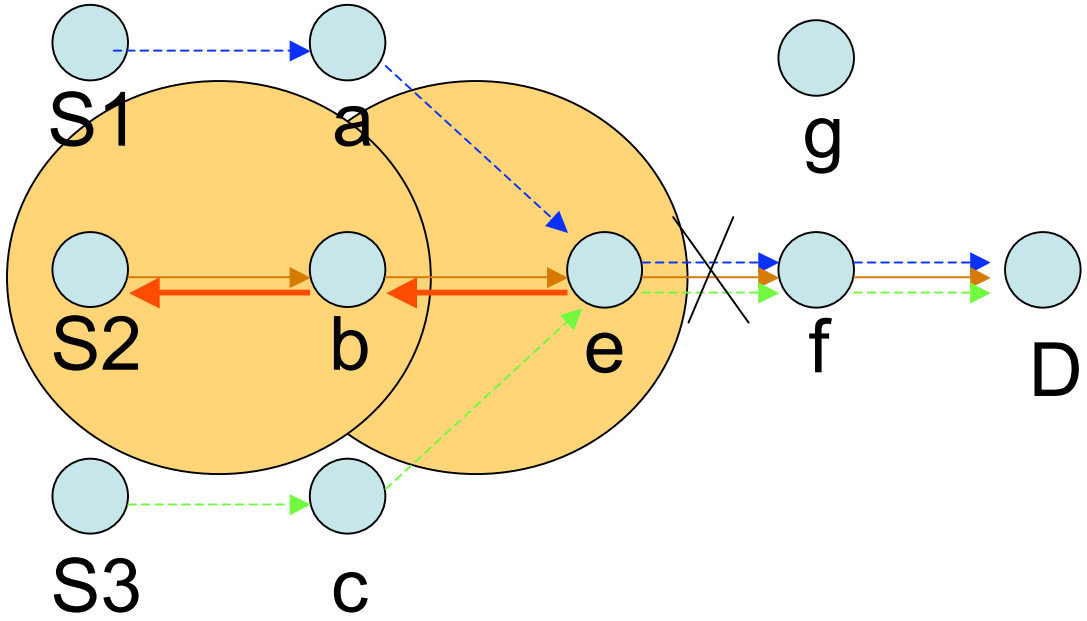
Handling of Link Breaks in AODV

- Local Repair
- Precursorlist for RERR delivery



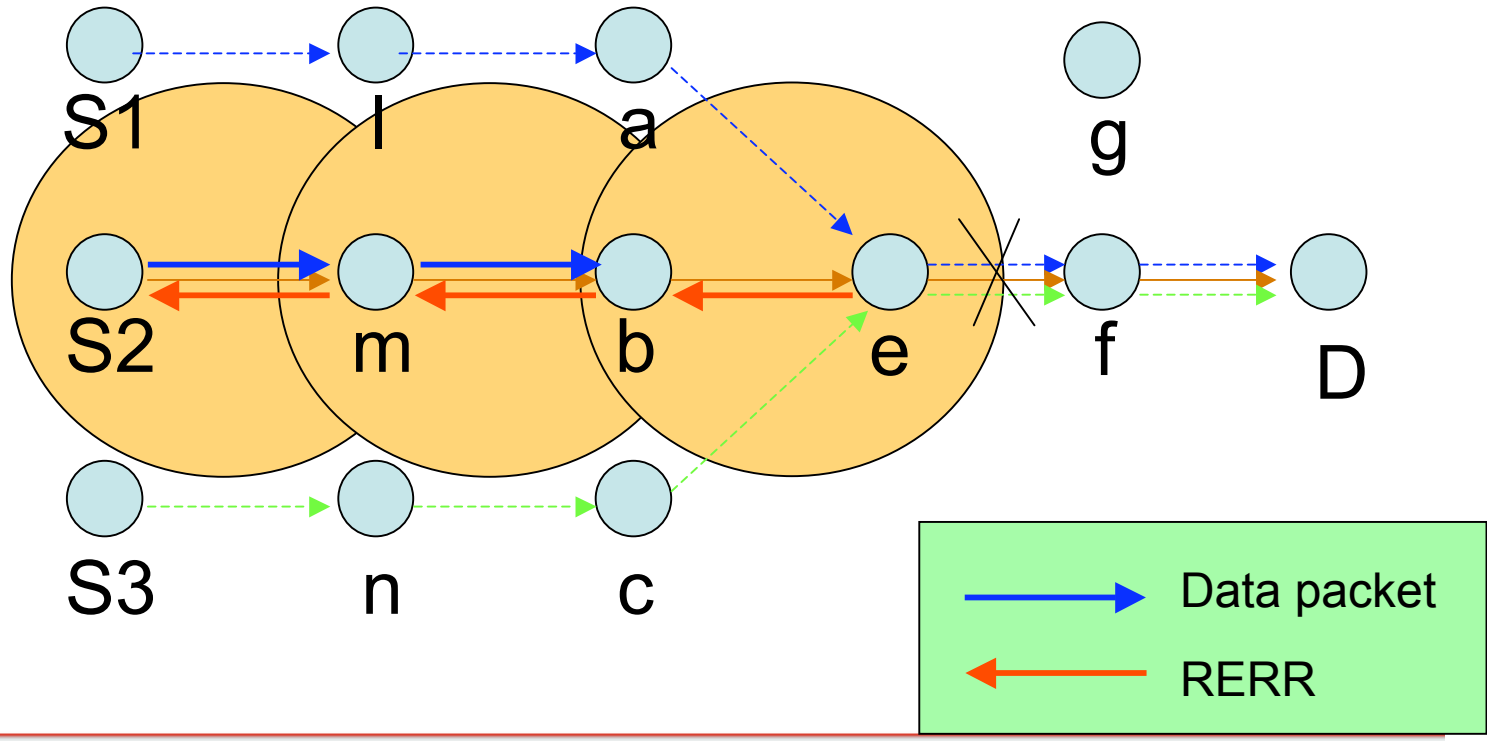
Handling of Link Breaks in LOAD

- Solution 1)
  - Utilize the source address of data packet to send RERR t o the originator (without precursorlist)
  - Node on an active route keeps a reverse route entry for s ending RERR to the originator



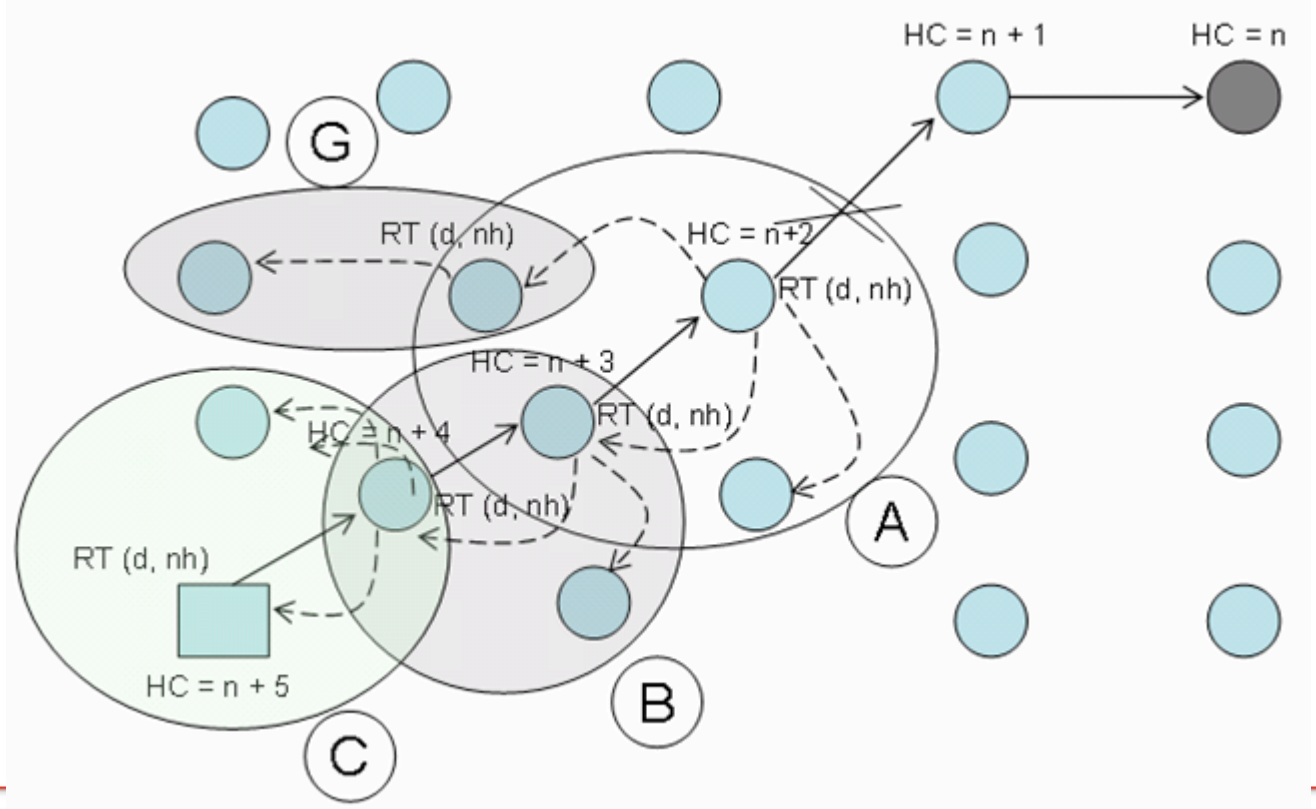
Handling of Link Breaks in LOAD (2)

- Solution 2)
  - Unicast RERR back only to the previous hop nod e

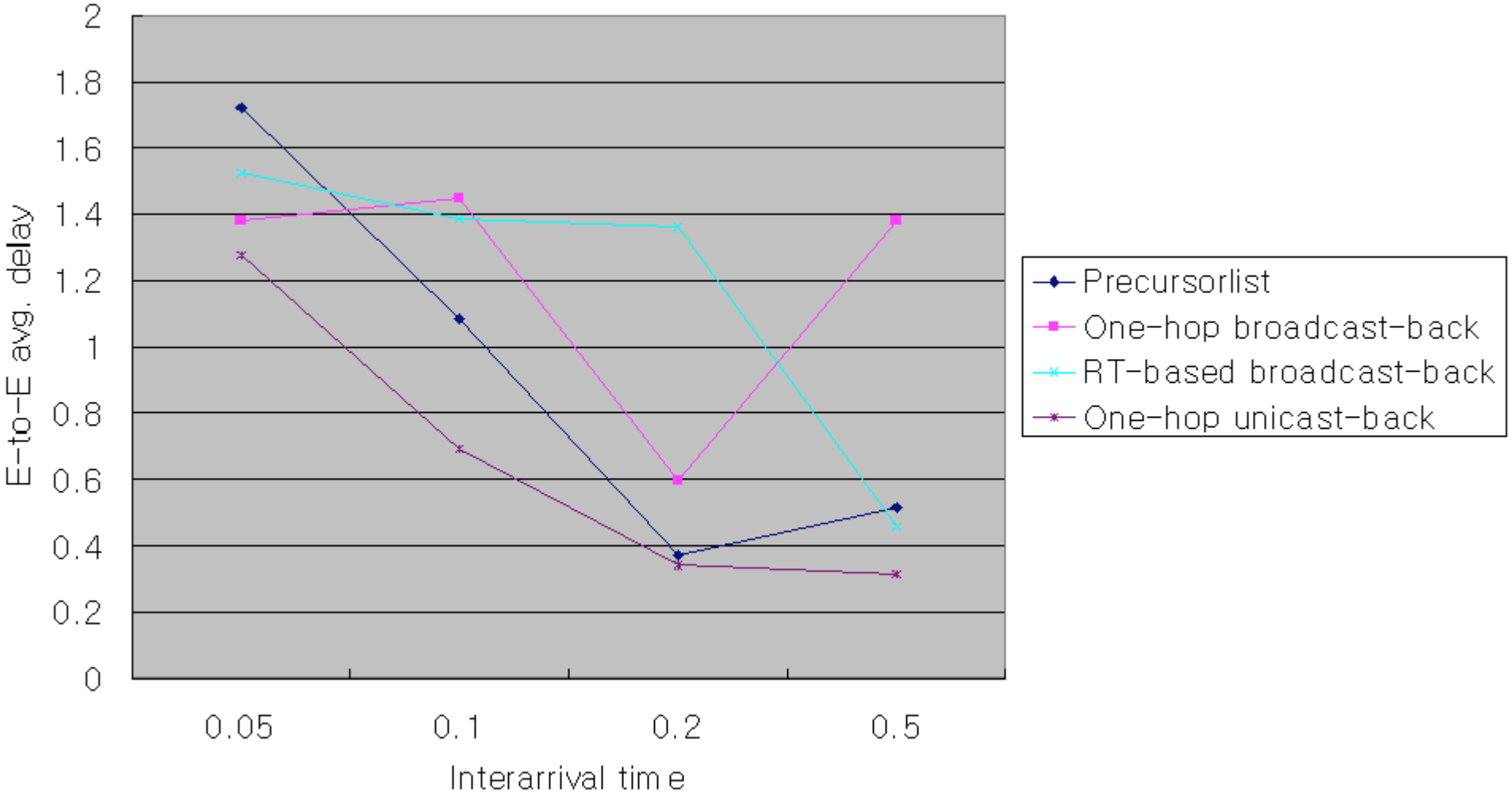


Handling of Link Breaks in LOAD (3)

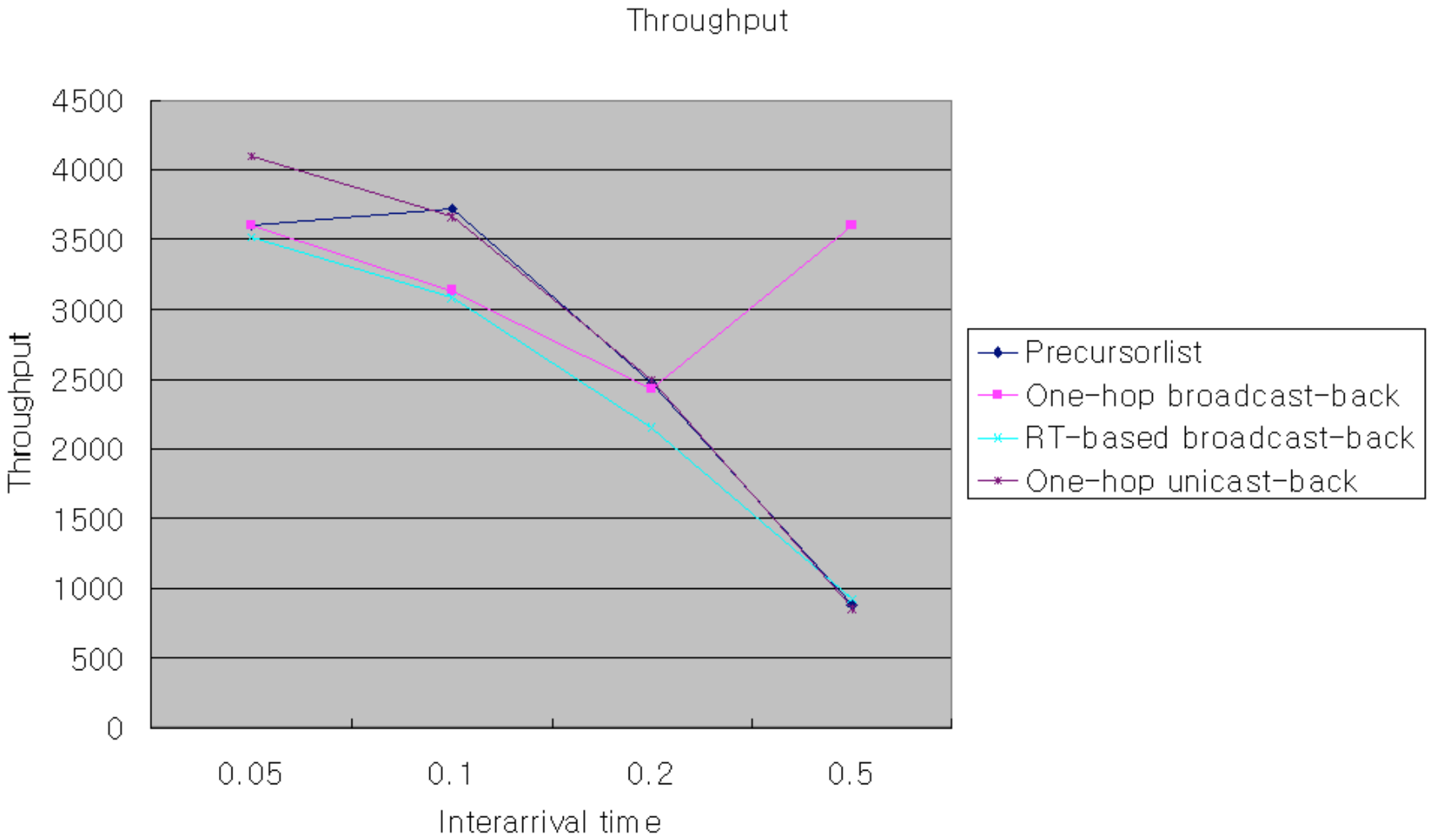
- Solution 3)
  - Broadcast RERR back by utilizing Routing table entries



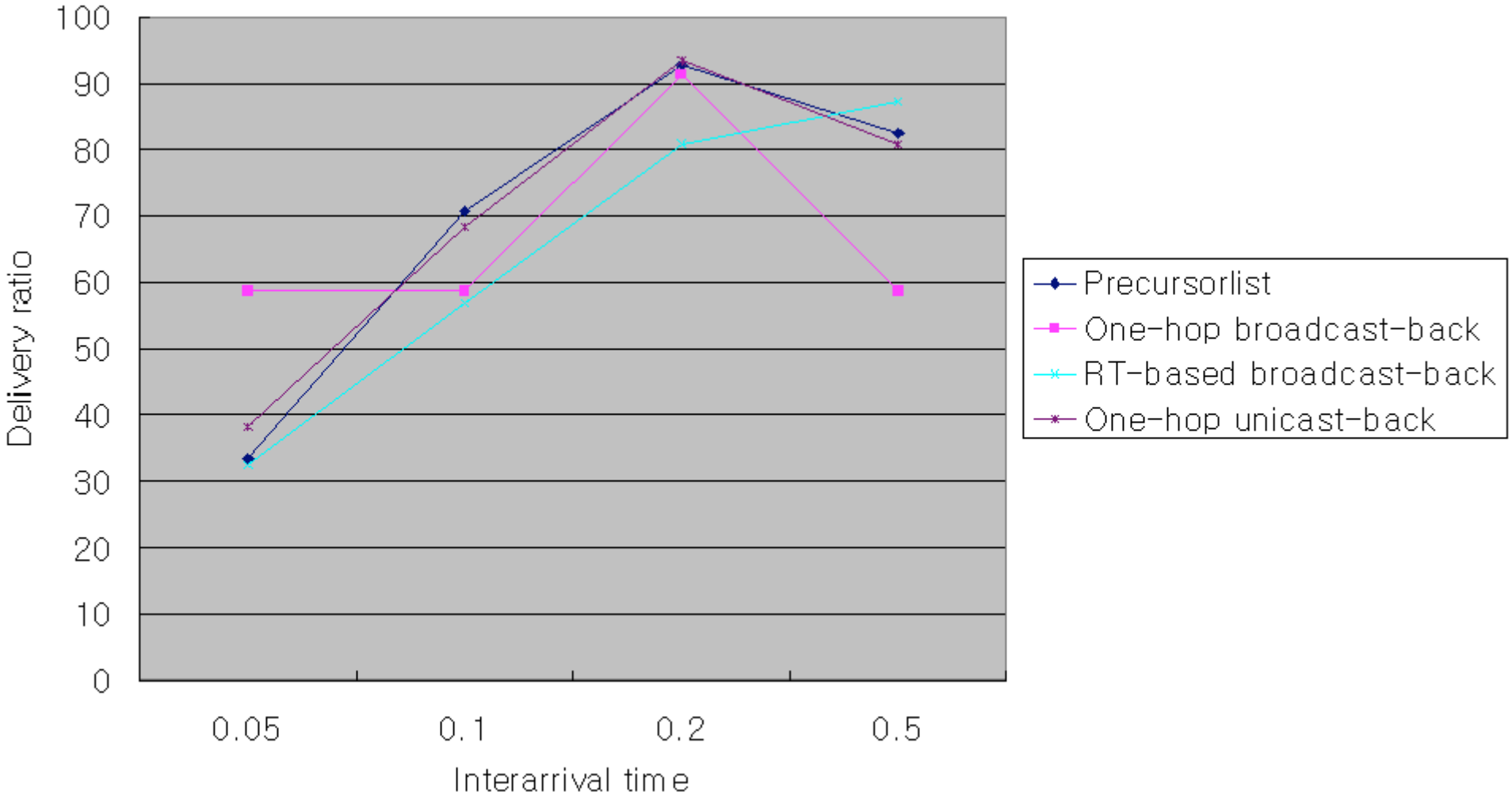
End-to-End Delay



Throughput


Throughput
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Throughput
0.05
0.1
0.2
0.5
Interarrival time
Precursorlist
One-hop broadcast-back
RT-based broadcast-back
One-hop unicast-back

Delivery Ratio



Dynamic MANET On-demand for 6LoWPAN (DYMO-low) Routing

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S. Daniel Park (SAMSUNG Electronics)
I. Chakeres (Boeing Phantom Works)
S. Yoo(Ajou University)

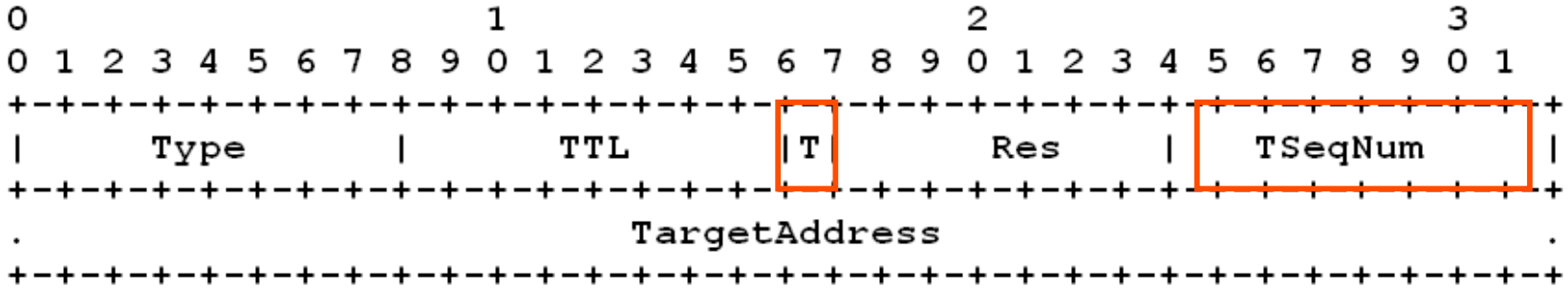
draft-montenegro-6lowpan-dymo-low-routing-00.txt

Simplification from DYMO

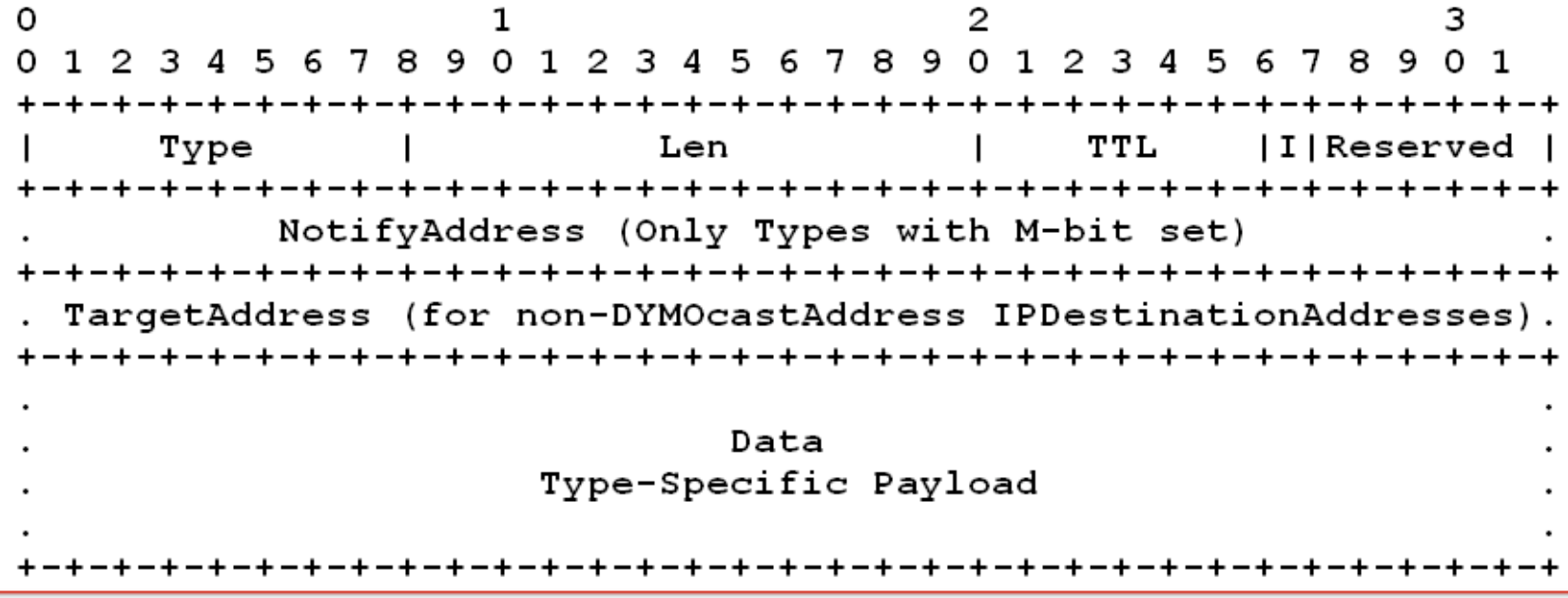
- Obviates UERR (Unsupported Element Error)
- DYMOcast is mapped as broadcast
- No path accumulation
  - Only one Routing Block (RBlock)
- Only the final destination responds
- Allow Multiple Routing Elements (RE)
  - Possibly reduce the number of control messages by aggregation
- Limit on the number of control message
- Inserted the Error Code field into RERR
- Utilize LQI for route cost calculation
- Do not use HELLO message and Sequence Number

Generic Element Structure

DYMO-low:

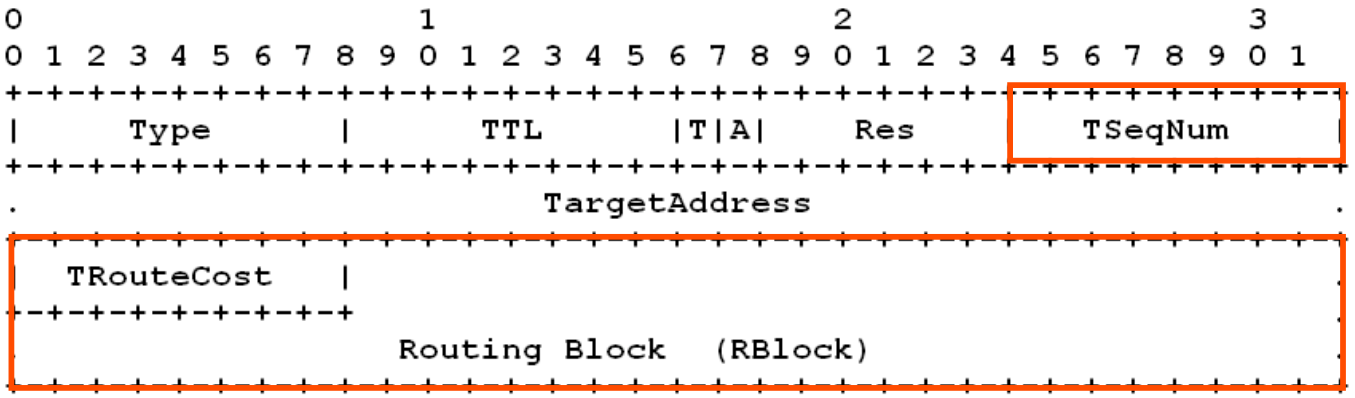


DYMO:

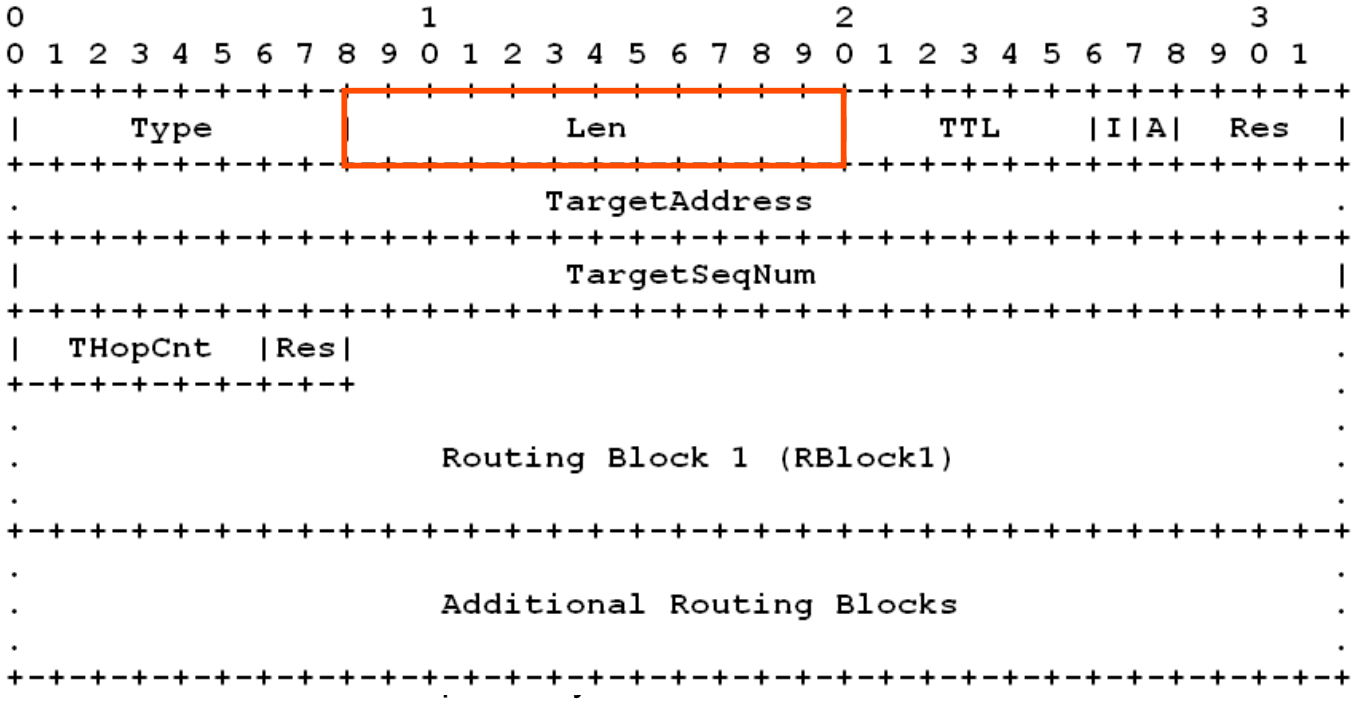


Routing Element (RE)

DYMO-low:

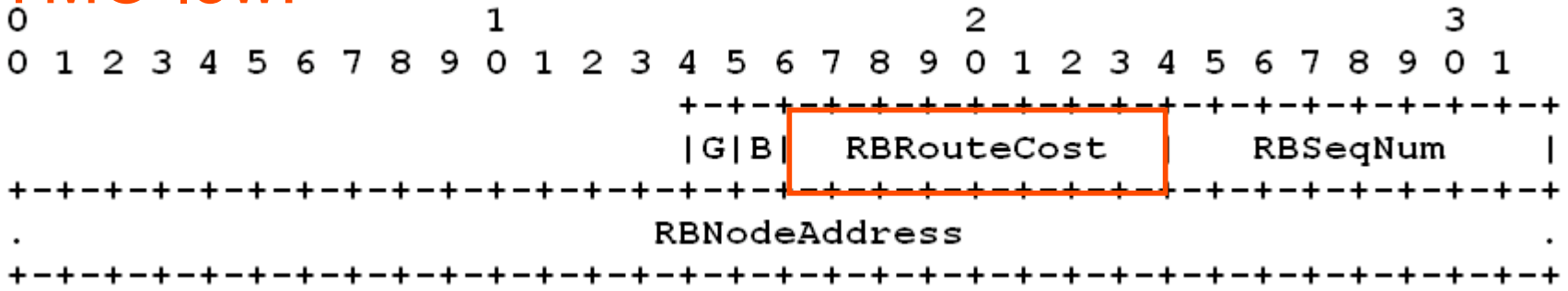


DYMO:

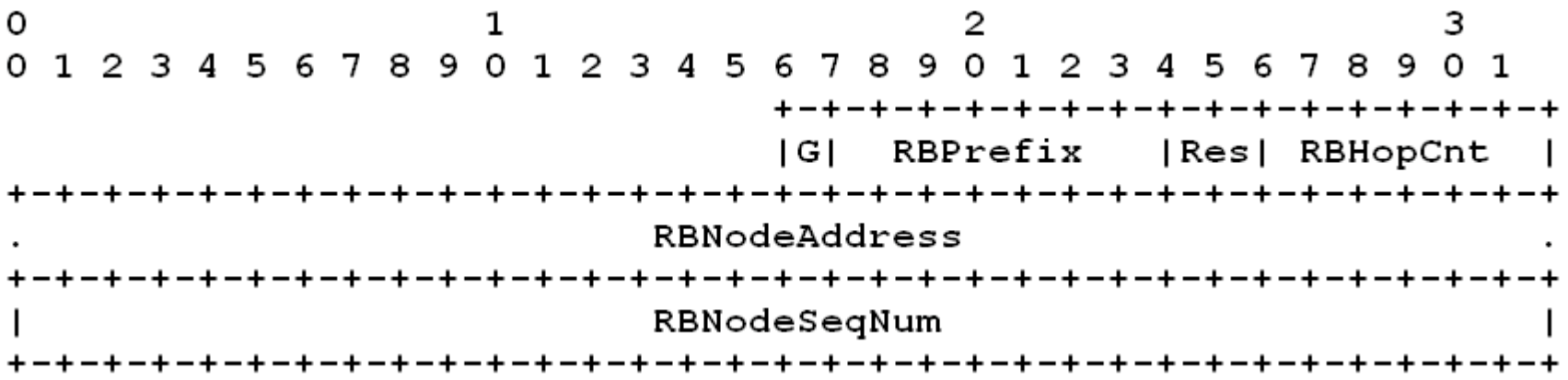


Routing Block (RBlock)

DYMO-low:

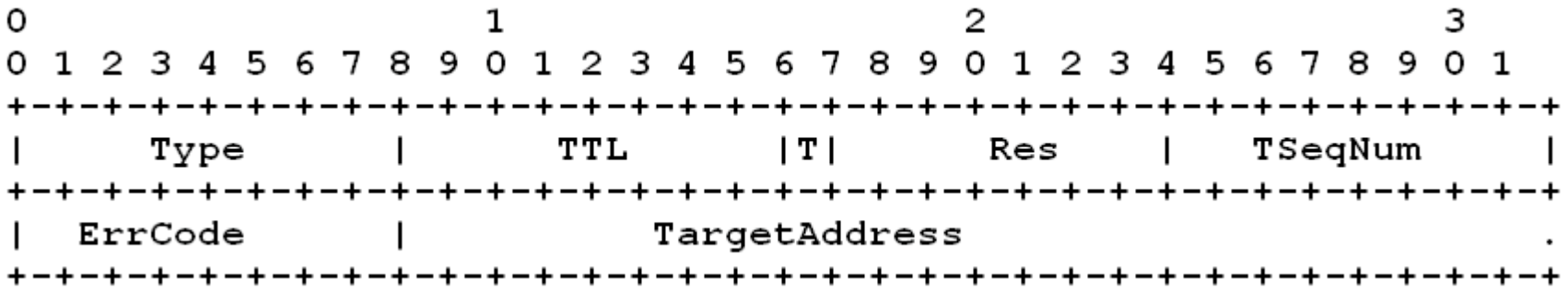


DYMO:

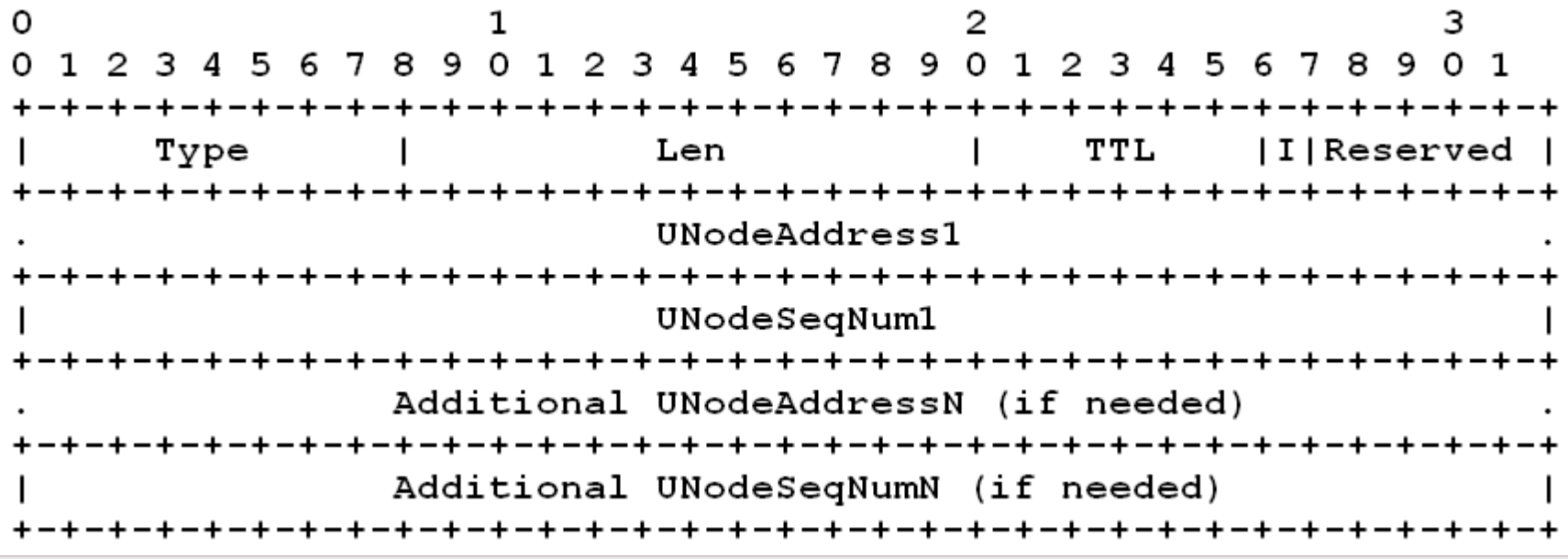


Route Error (RERR)

DYMO-low:



DYMO:



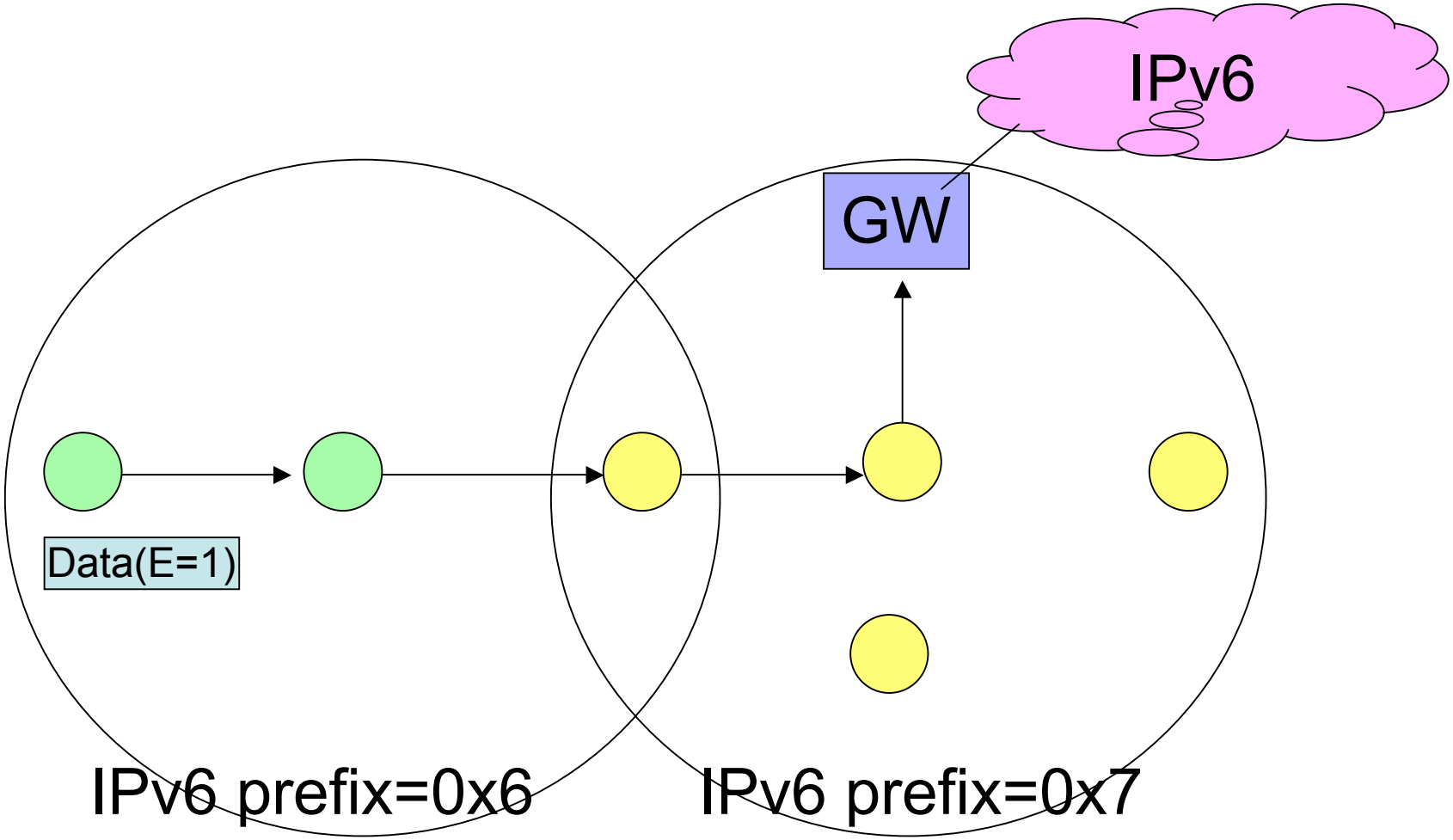
Comparison of Routing Protocols for 6lowpan

	LOAD	DYMO-low	AODV	TinyAODV	ZigBee	AODVjr
RERR Message	**Use**	**Use**	**Use**	**Use**	**Use**	**No Use**
Sequence number	**No Use**	**Use**	**Use**	**Use**	**No Use**	**No Use**
Precursor lists	**No Use**	**No Use**	**Use**	**No Use**	**No Use**	**No Use**
Gratuitous RREP	**No Use**	**No Use**	**Use**	**No Use**	**No Use**	**No Use**
Hop count	**Opt**	**Opt**	**Use**	**Use**	**No Use**	**No Use**
Hello messages	**No Use**	**No Use**	**Use**	**No Use**	**No Use**	**No Use**
Local repair	**No Use**	**No Use**	**Use**	**No Use**	**Use**	**No Use**
Energy Usage	**Low**	**Low**	**High**	**Low**	**Low**	**Low**
Memory Usage	**Low**	**Low**	**High**	**Low**	**Low**	**Low**
Link-layer feed back	**Use**	**Use**	**Opt**	**No**	**Opt**	**No**
Mobility	**Mobile/Static**	**Mobile/Static**	**Mobile**	**Mobile**	**Mobile/Static**	**Mobile**
Control Packet Aggregation	**No Use**	**Use**	**No Use**	**No Use**	**No Use**	**No Use**

Interoperability with Internet

- How can we route traffic to the external IPv6 network?
  - Allow different IPv6 Prefixes on WPANs?
    - If 6lowpan allows inter-PAN routing, this isn't enough f or identifying outbound traffic to external IPv6 network
  - Use of default GW?
    - Add 1 bit flag(E) in the Adaptation layer format for ide ntifying outbound traffic to external IPv6 networks → F FDs forward those packets(E=1) to the default GW.
    - GW MAY advertise itself periodically

Handling outbound traffic to external IPv6 networks



Open Issues

- Considering the route cost
  - Leave the route cost to be the implementation is sues?
    - Parameters: Hop counts, LQI, remaining energy of no des, etc.
- Use of the 16bit address/EUI-64 address
- Routing scalability
  - Limit the size of the 6lowpan?
- Interoperability with Internet – Default Router

6LoWPAN Evaluation Results

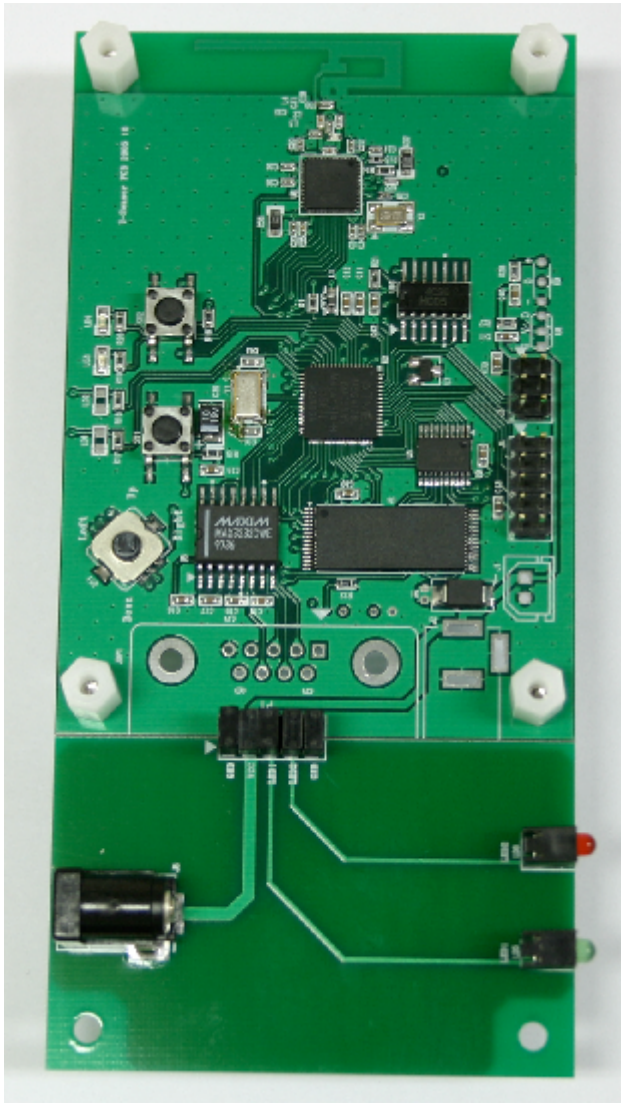
Ki-Hyung Kim (Ajou University) and
S. Daniel Park (SAMSUNG Electronics)

Contents

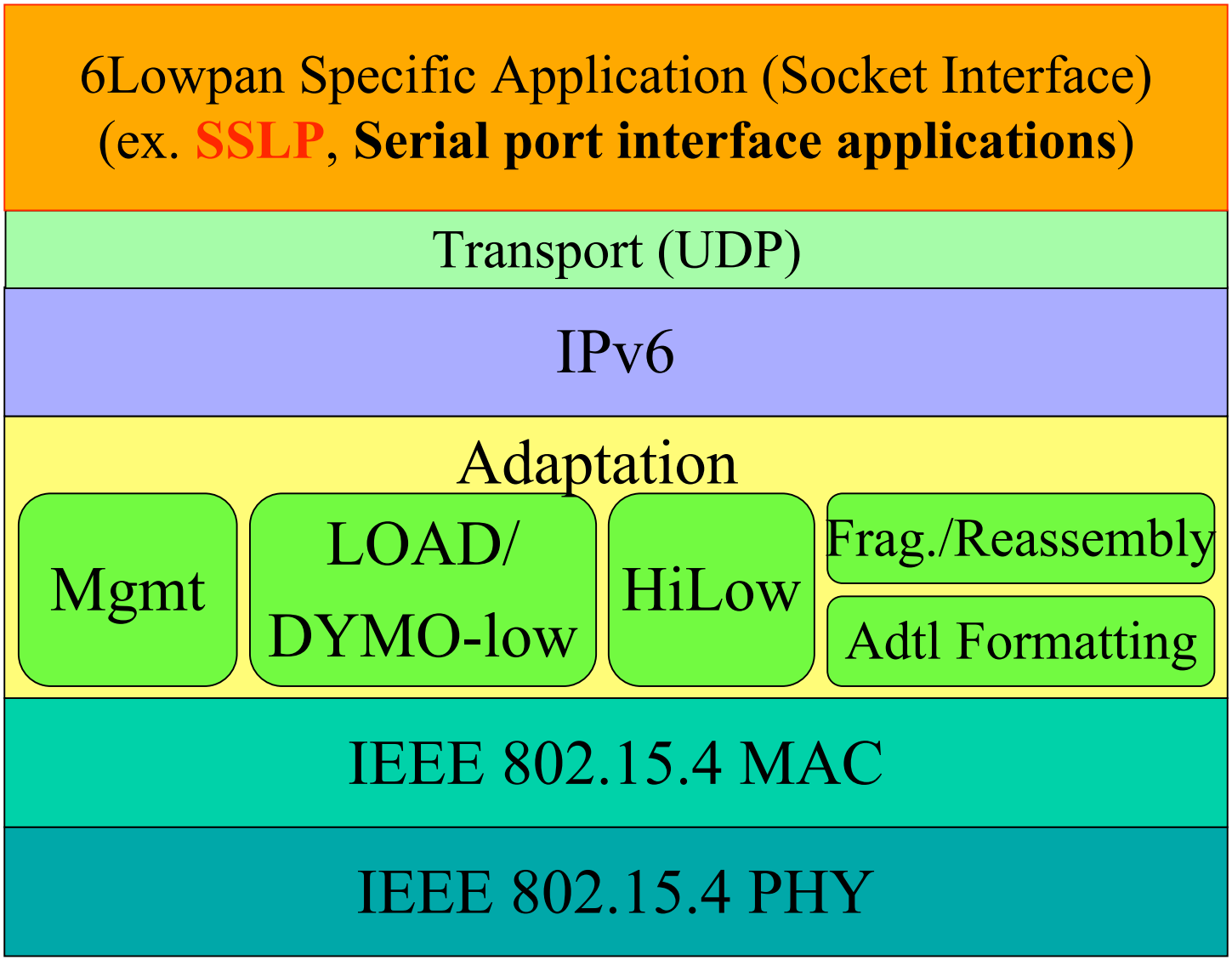
- Realization Platform
  - Implementation of 6lowpan
  - Implemented Protocol Stack
  - Preliminary Evaluation Results for Implementation
- Simulation model of 6lowpan on NS-2
  - Preliminary Simulation Results
- Hierarchical Routing Protocol (HiLow)
- Simple Service Location Protocol (SSLP)

Realization Platform

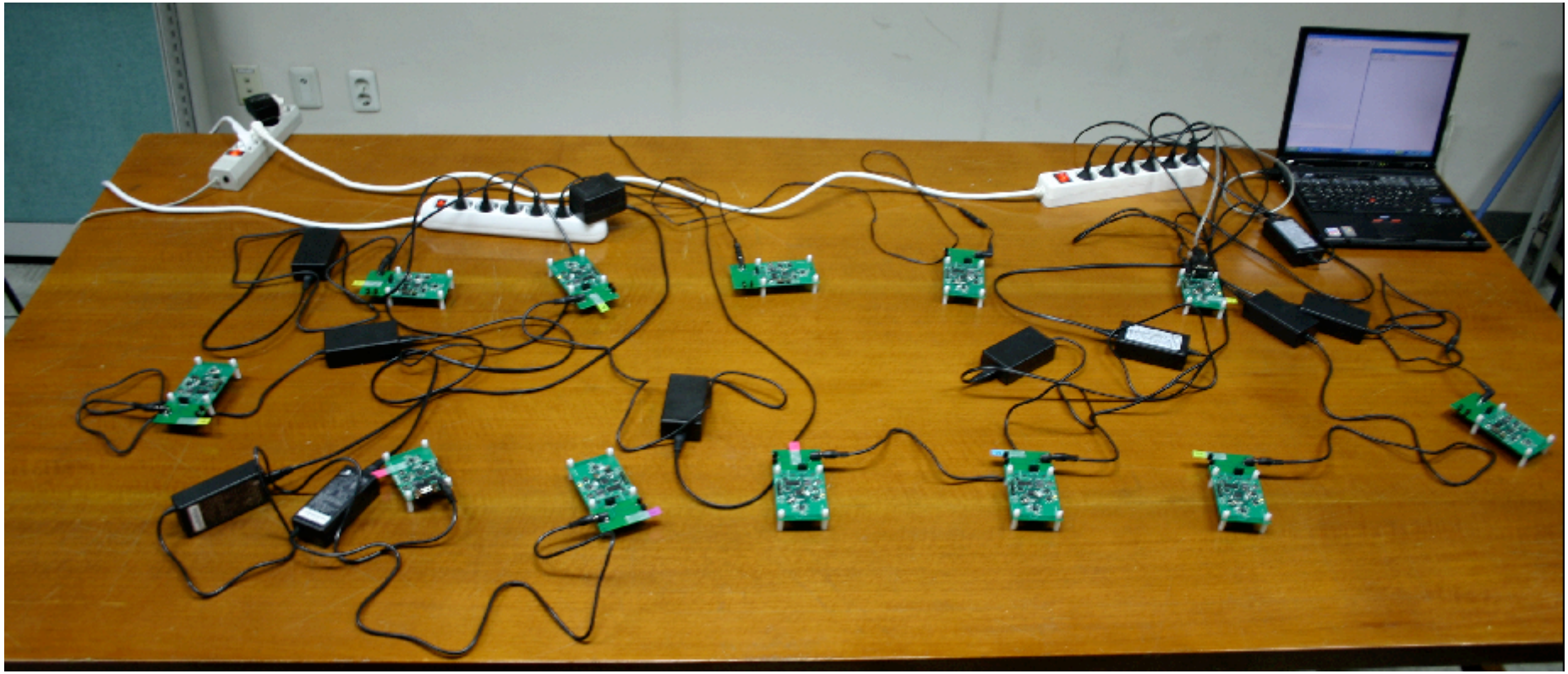
- Hardware Platform
  - Custom built prototype referenced from c c2420dbk of Chipcon
    - MCU: AVR Atmega128L, MAC: Chipcon C C2420
- Implemented Protocols
  - draft-ietf-6lowpan-format
  - draft-daniel-6lowpan-load-adhoc-routing
  - draft-daniel-6lowpan-hilow-hierarchical-routing
- Currently Implementing
  - draft-daniel-6lowpan-sslp
  - draft-montenegro-6lowpan-dymo-low-routing



Protocol Stack

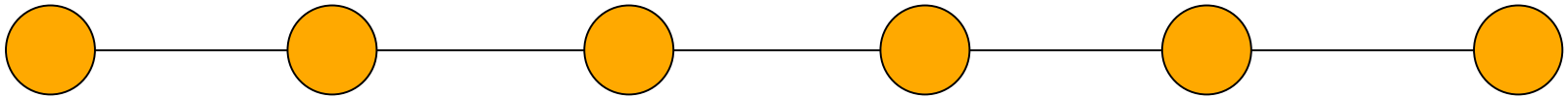


Testbed Setup

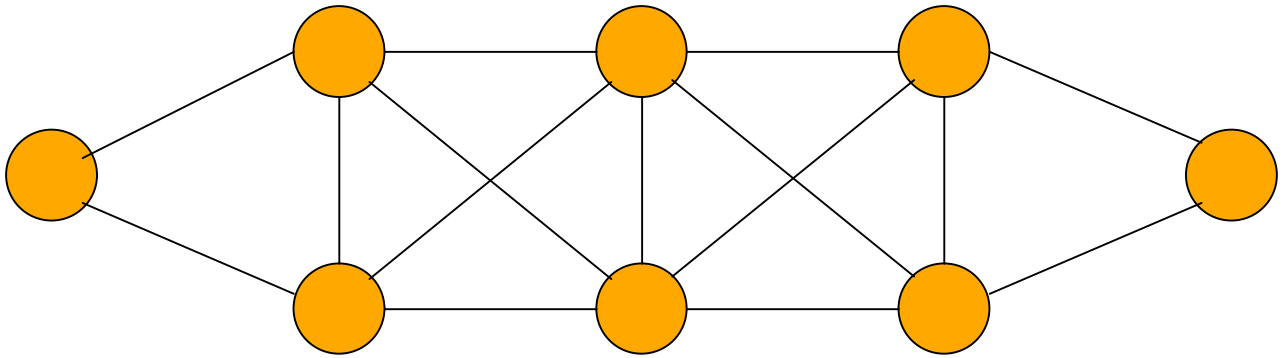


Topologies for Evaluation

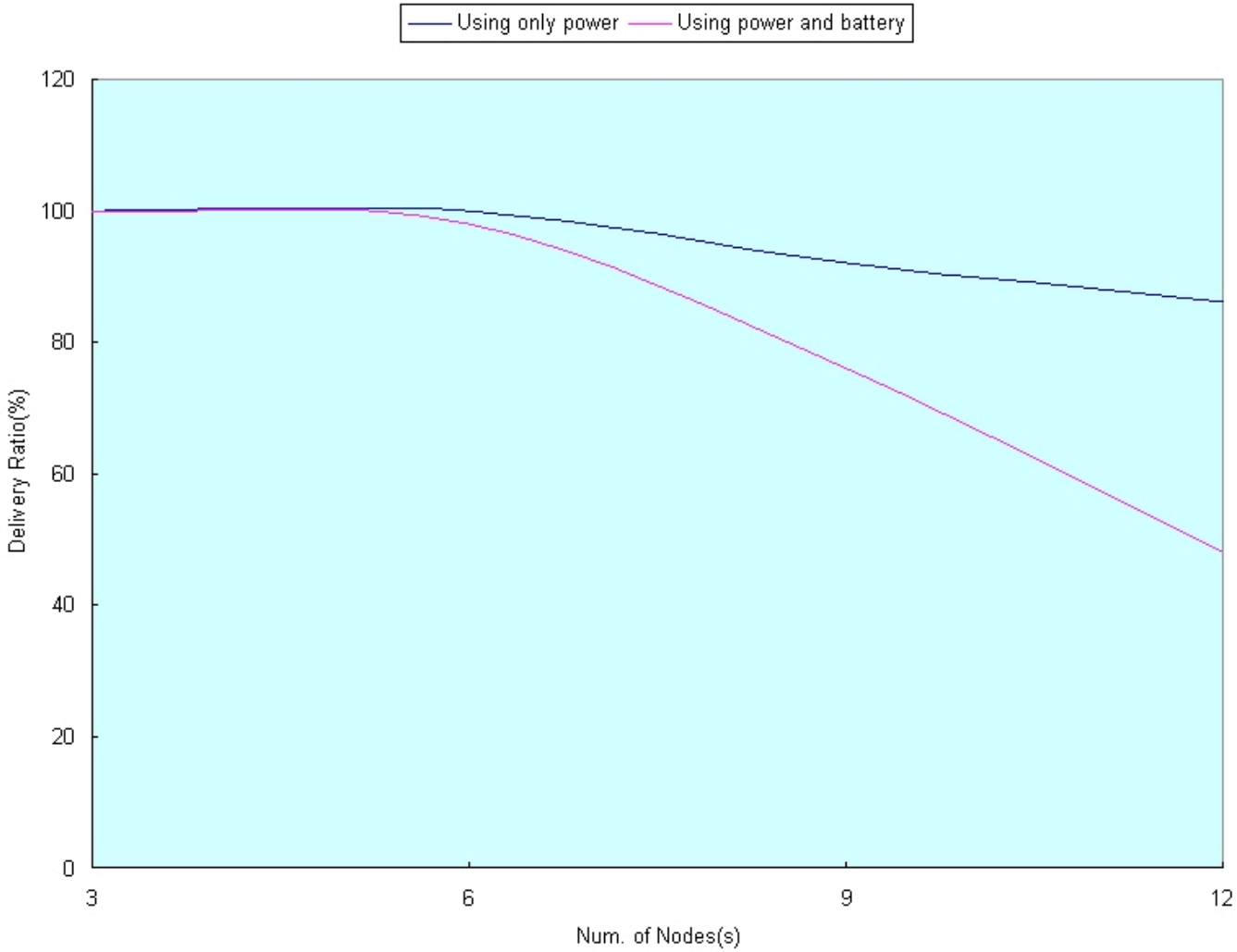
- Topology 1:
  - Varying # Nodes (3, 6, 9, 12)



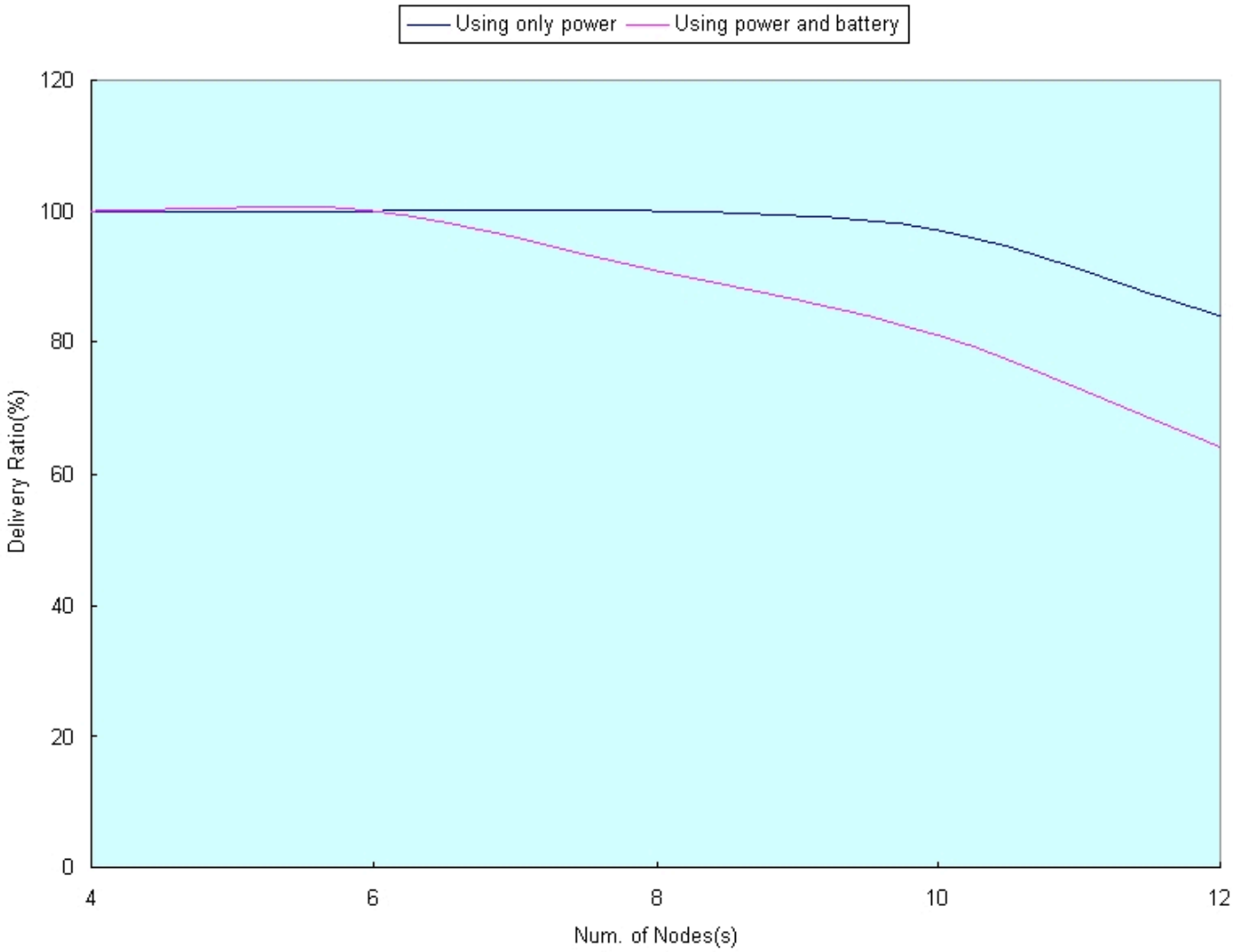
- Topology 2:
  - Varying # Nodes (4,6,8,10,12)



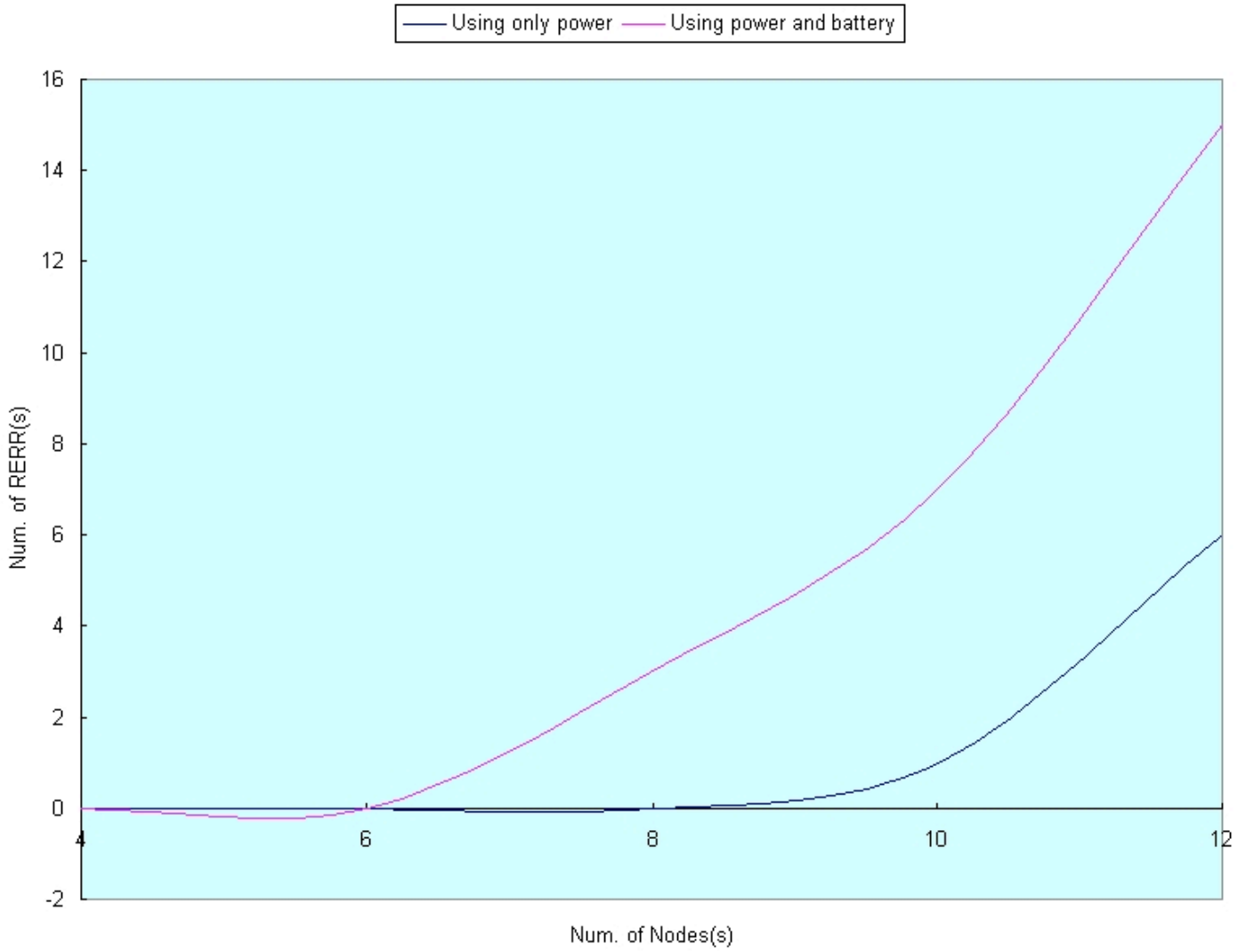
Delivery Ratio for Topology 1



Delivery Ratio for Topology 2

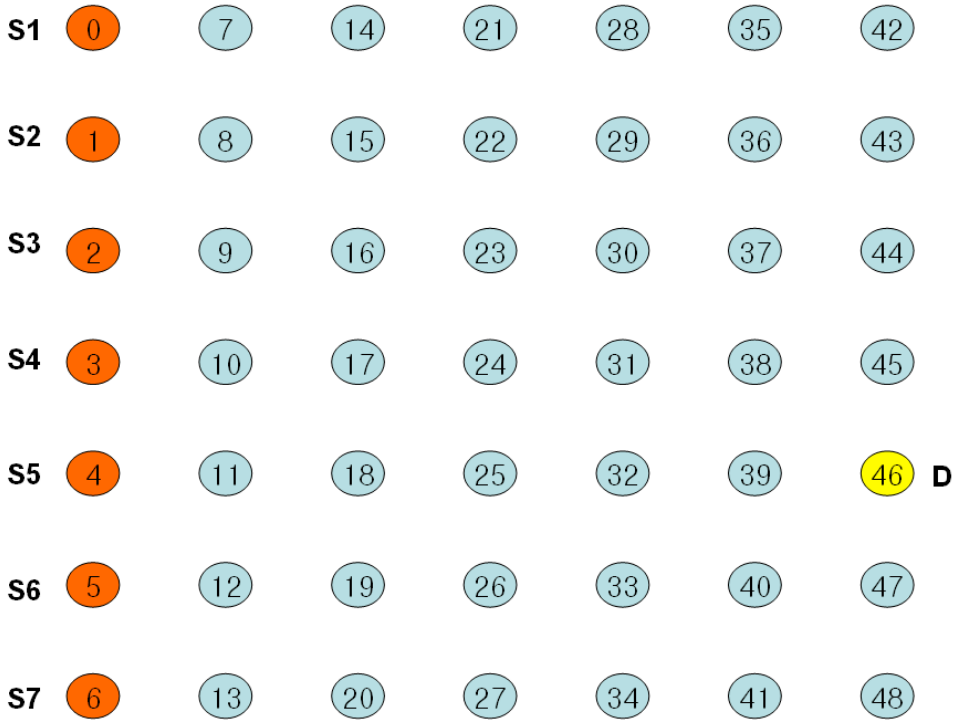


Num. of RERRs for Topology 2

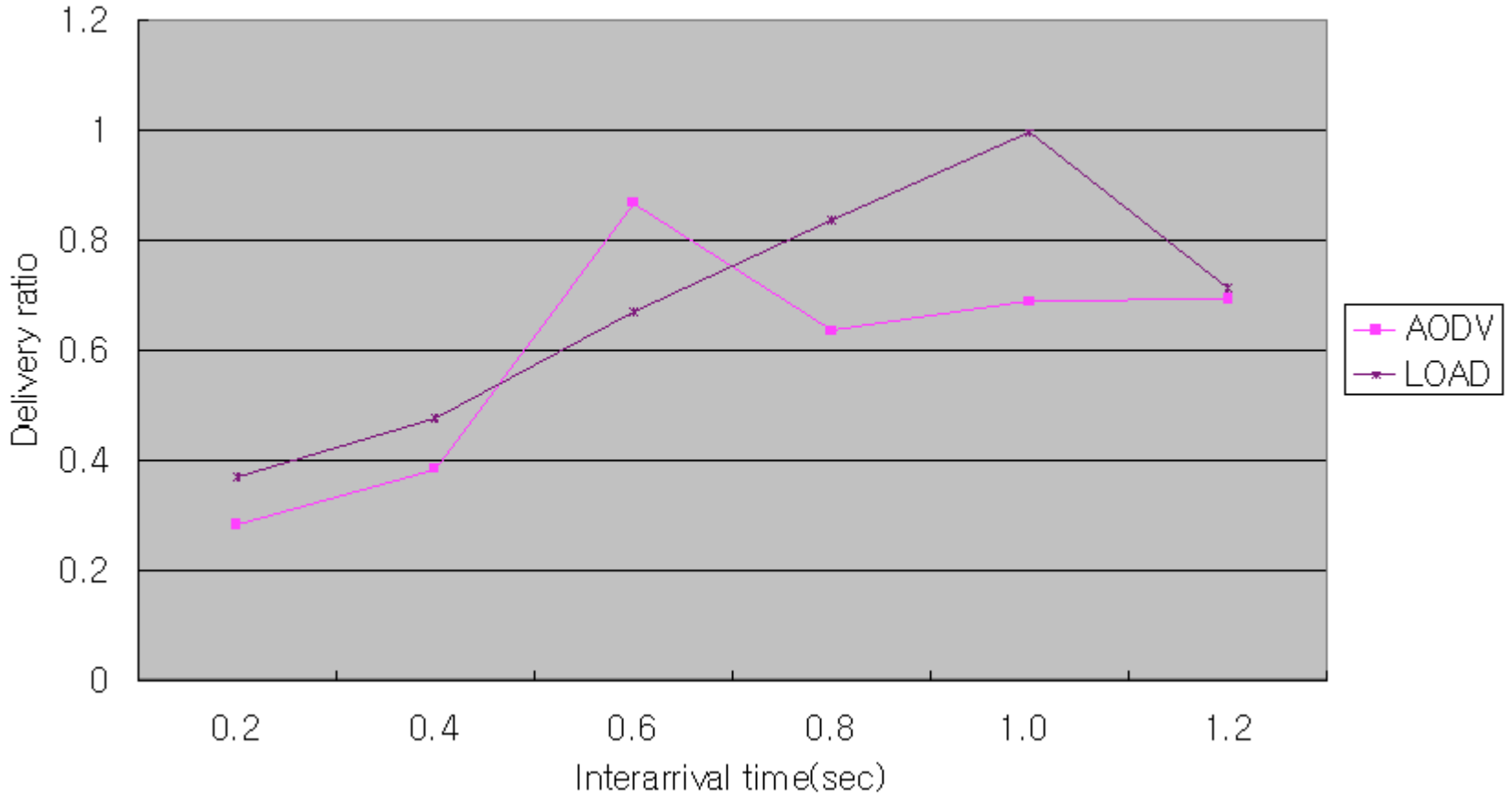


Simulation Framework

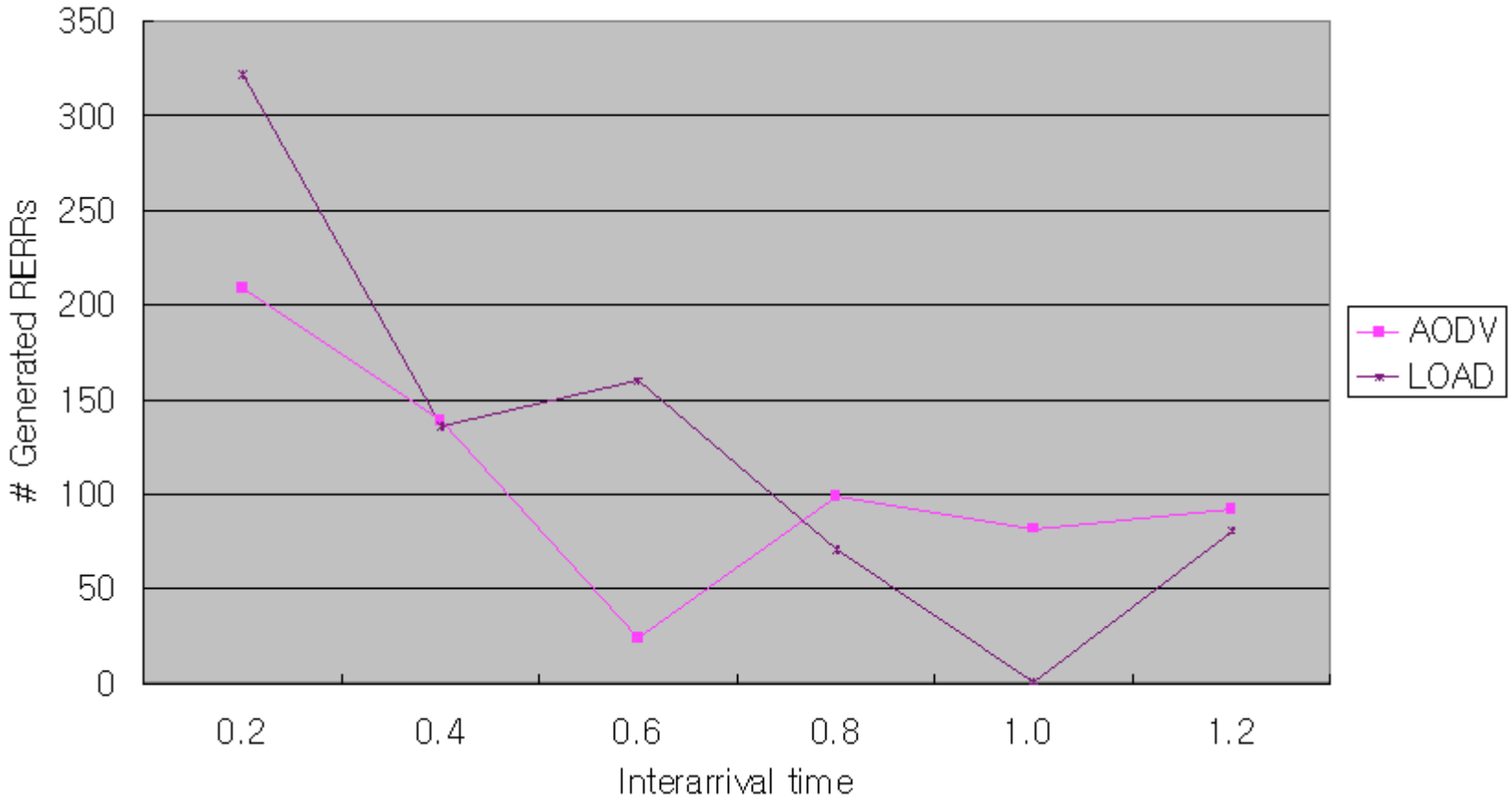
- Implements LOAD by NS-2
- Uses IEEE 802.15.4 MAC by CUNY
- Topology
  - 7x7 Grid
  - 7 Sources
  - 1 Destination



Delivery Ratio

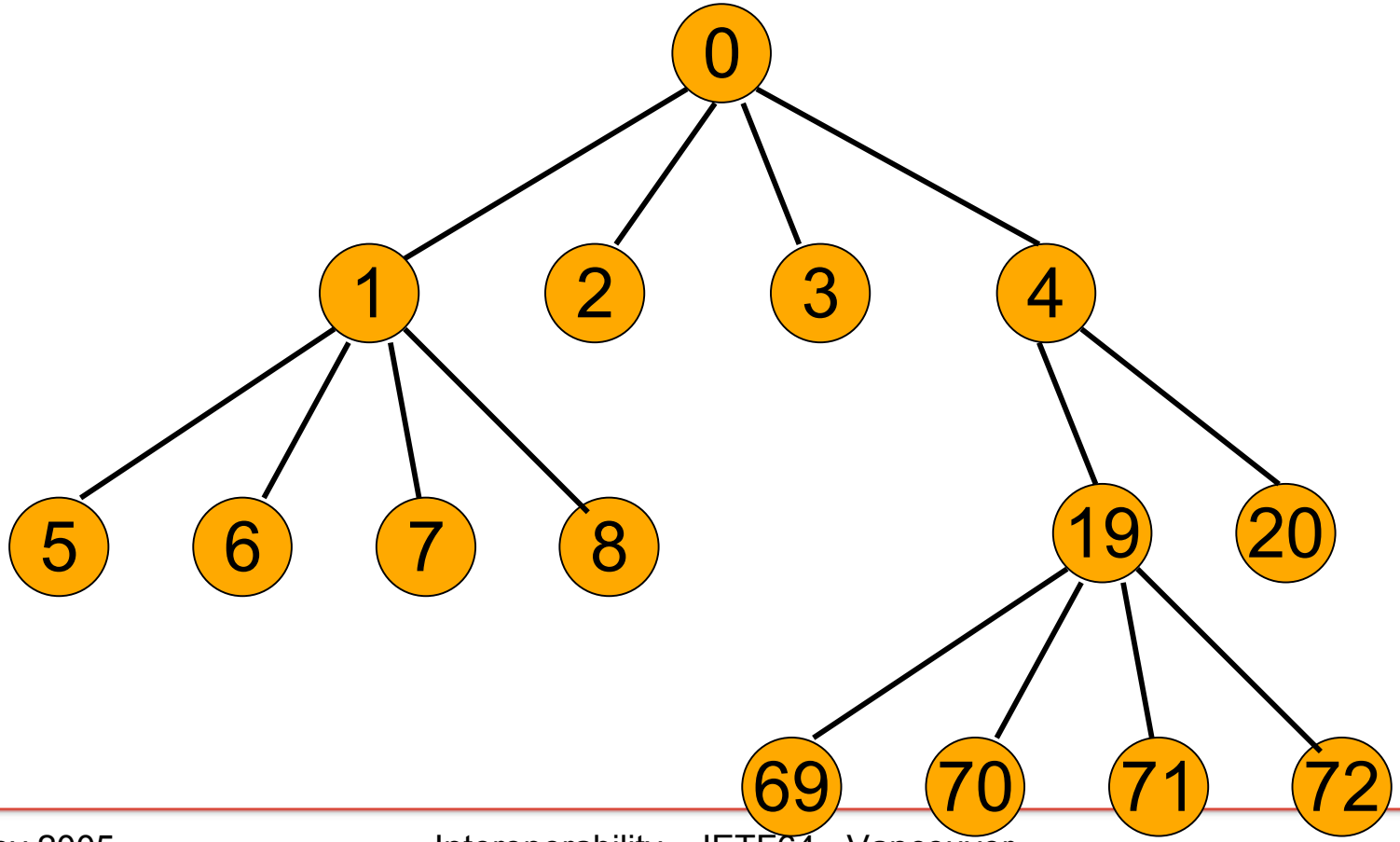


Generated RERRs



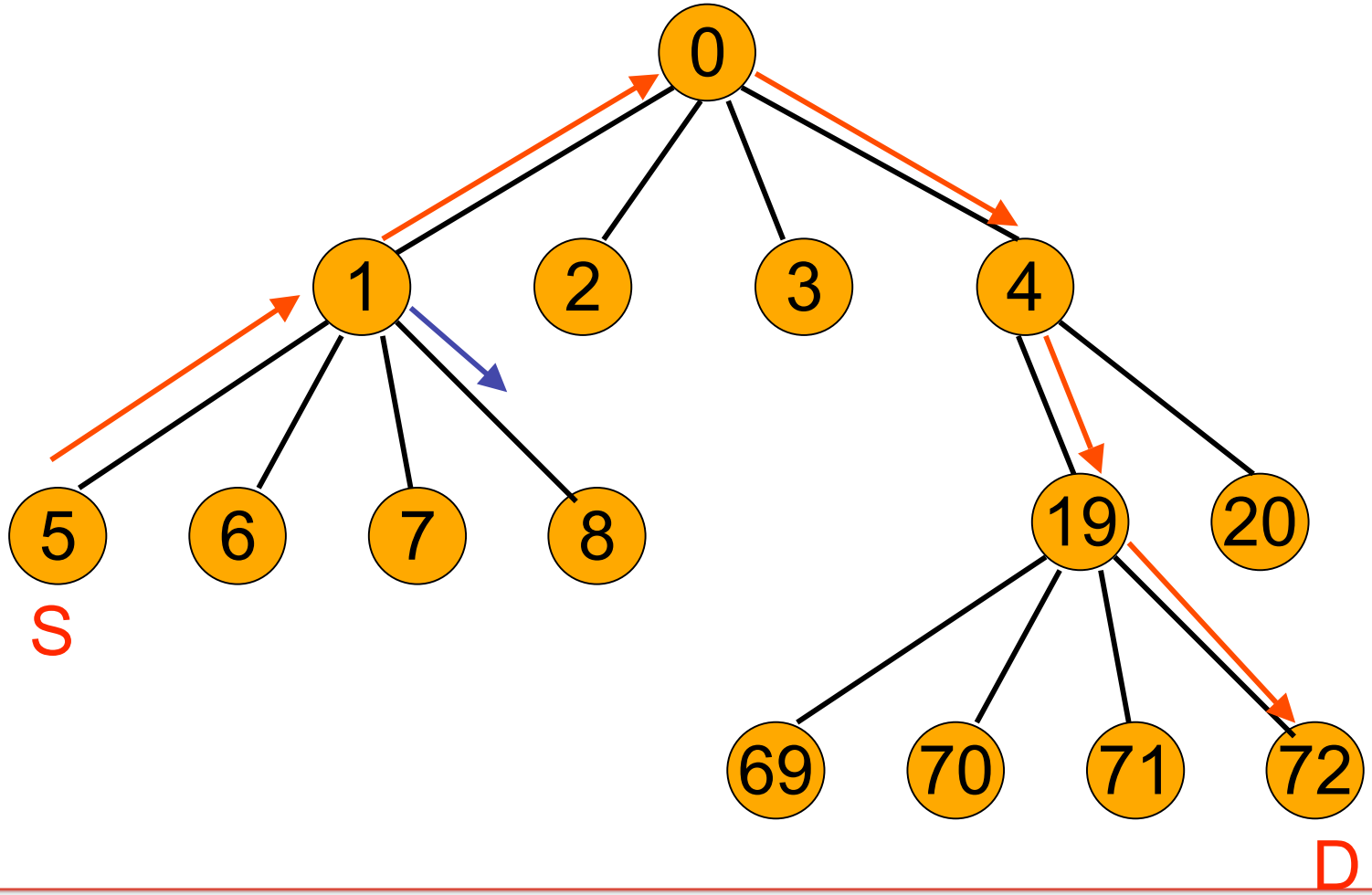
Dynamic Assignment of Short Address (HiLow)

- No Depth Limitation of trees
  - The only parameter is MC: Maximum number of Children
  - Efficient for gradually incremental networks



Hierarchical Routing (HiLow)

- No need of routing tables



Routing Algorithm for HiLow

- If C is the member of SA:
  - The next hop node is AA(DC+1, D).
- If C is the member of SD:
  - The next hop node is AA(DC-1, C).
- Otherwise:
  - The next hop node is AA(DC-1, C).

, Where AA (D, k) : the address of the ascendant node of depth D of the node k

SA, SD: Sets of ascendant nodes and descendant nodes

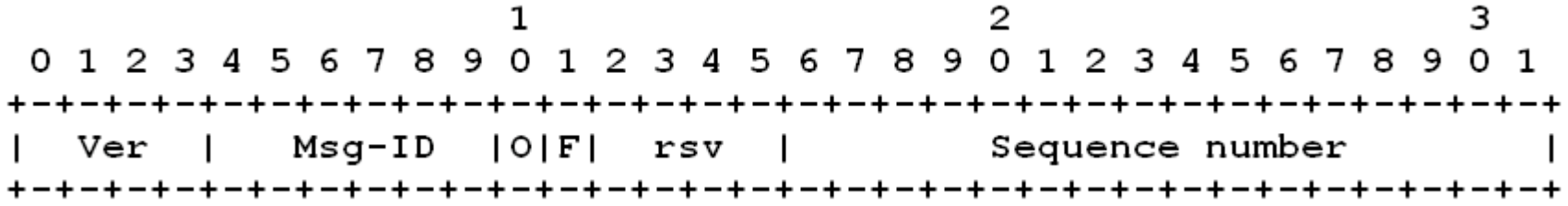
C: Current node

Simple Service Location Protocol(SSLP)

- When 6lowpan nodes come in close proximity, they need to locate one another and services in proximity
- Related Works
  - SLPv2 in Internet
  - SSDP(Simple Service Discovery Protocol) of UPnP
  - Jini
- These are not suitable for 6lowpan
  - Limited packet size
  - Limited processing power
  - Dynamic nature of network topology
- SSLP
  - Provides mechanisms for locating services and peer nodes in proxi mity
  - Interoperates with SLPv2 on Internet

SSLP Header Format (1)

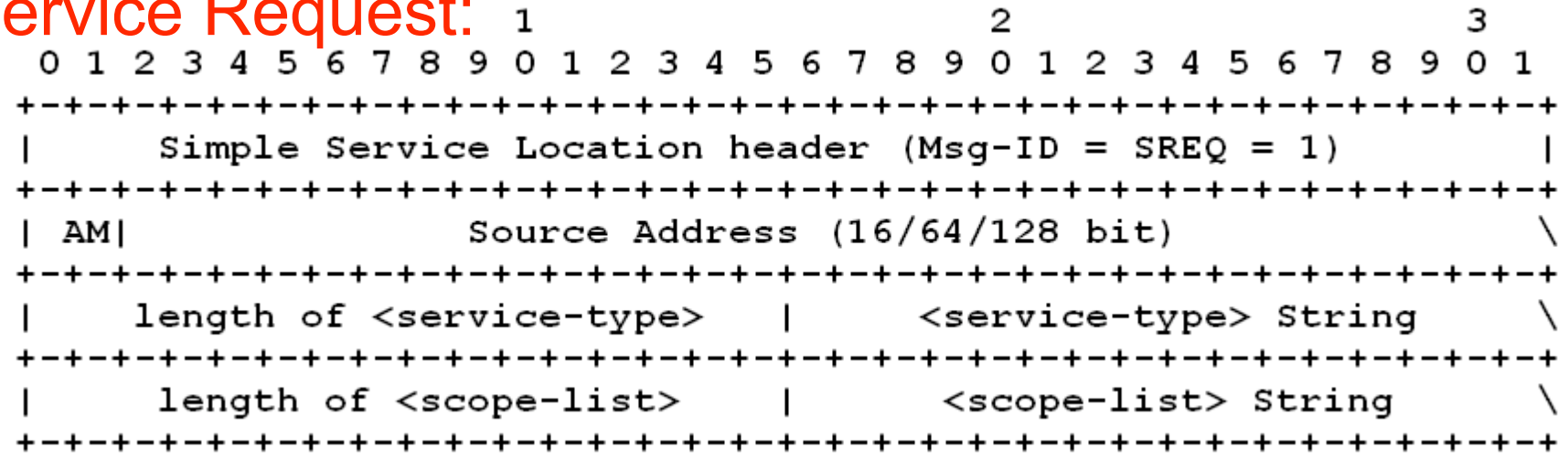
- SSLP General Header



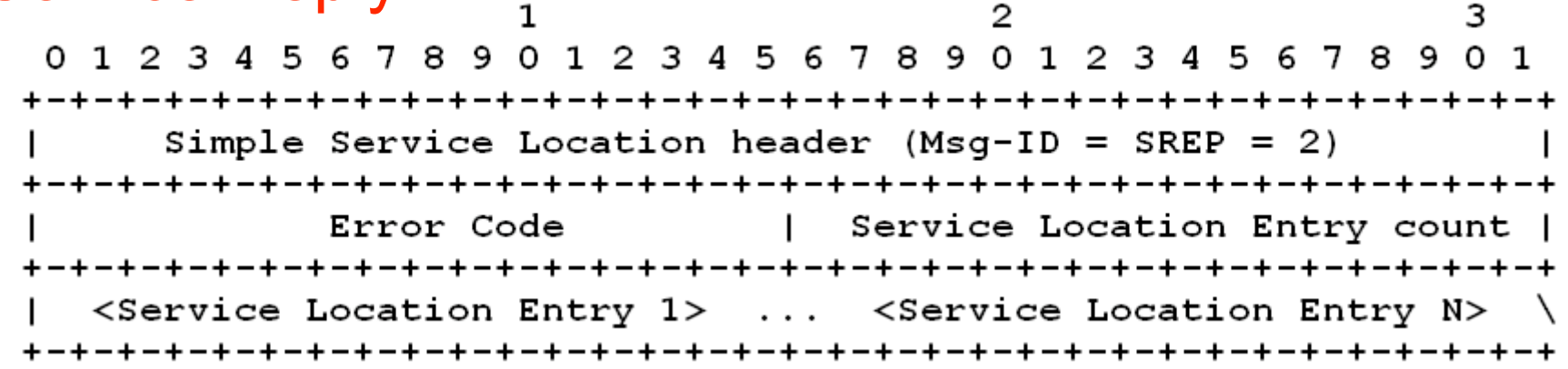
Message Type	Abbreviation	Msg-ID
Service Request	SREQ	1
Service Reply	SREP	2
Service Registration	SREG	3
Service Deregistration	SDER	4
Service Acknowledge	SACK	5
DA Advertisement	DADV	6
SA Advertisement	SADV	7

SSLP Header Format(2)

Service Request:



Service Reply:



Next steps

- Feedback is welcome
- Any comments/suggestions?