Support for Mobile and Low-Powered Wireless Devices in IPv6

Ravi Prakash
Department of Computer Science
University of Texas at Dallas

Motivation

- Two areas of network growth:
  1. Mobile (wireless) devices.
  2. Low-power (multi-hop) wireless personal area networks.
- Challenges:
  - Changing network connectivity.
  - Low-bandwidth.
  - Lossy links.
  - Low energy storage.

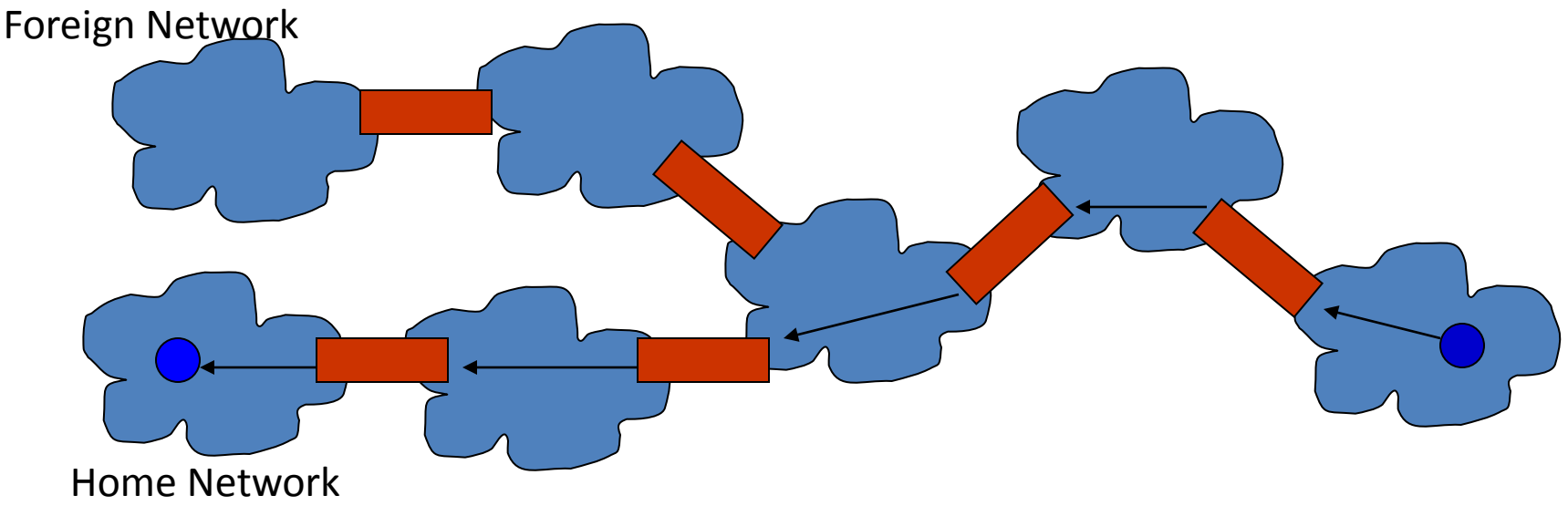
Mobile IPv6

Operation Scenario

- Mobile node moves out of its home network, and into a foreign network.
- Other nodes unaware of the current location of mobile node.
- Situation: other nodes send packets addressed to mobile node's home address.
- Goal: deliver these packets to the mobile node at its current location.

IP Forwarding Without Mobility Support

- Routers forward the packet based on destination's home IP address.
- Packet reaches a router with interface to the destination's home network.
- The router injects the packet into the home network.
- Delivery failure because destination is not present.

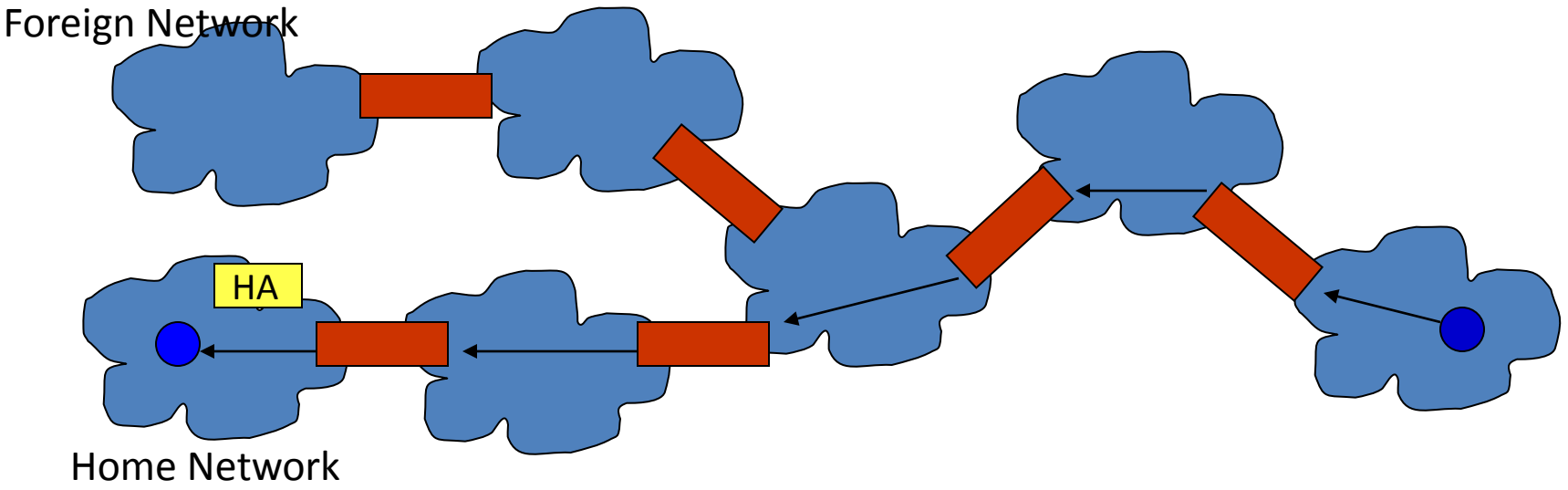


Adding Mobility Support

- Transparency: node mobility should be hidden from other nodes.
- Interoperability: mobile node should be able to communicate with other nodes, mobile as well as stationary.
- Security: unauthorized nodes should not be able to forge movement of nodes.
- Efficiency: keep protocol overheads small.
- Unconstrained addressing: Mobile IP should not place any additional constraint on assigning IP addresses to nodes.

Network Entities to Support Mobility

- Home Agent (HA): acts on behalf of mobile node when it is away from home network.
- Correspondent node: A node with which the mobile node is communicating.



Mobility Support Operations

- Agent discovery: operations performed to determine the identity of Home Agent(s).
- Registration: informing HA about the care-of address while mobile node is in a foreign network.
- Bidirectional Tunneling: Correspondent node and mobile node exchanging packets via HA.
- Route Optimization: Correspondent node and mobile node directly exchange packets.
- Deregistration: removing old care-of address when mobile node moves out of a foreign network.

Mobility Header in IPv6

- Specified by Next Header value = 135
- Specifies messages for:
  - Binding update
  - Binding refresh
  - Return routability procedure.

Home Agent Address Discovery

- Router advertisement: lists only the link-local address of router.
- H bit: when set, advertising router is a HA.
- Prefix option modified in ICMPv6 .
- R-flag added.
  - When set, Prefix option field contains router's global unicast IPv6 address(es).
- Each HA maintains (sorted by preference):
  - list of home agents on a link,
  - their global unicast IPv6 address(es),
  - their remaining lifetime.

Home Agent Advertisement

- Preference level associated with each advertised address.
- Each advertisement has a lifetime.
- Interval between successive advertisements: a fraction of the advertisement lifetime.
- Possibly multiple HAs on a link with different preferences: load balancing.

Home Agent Discovery

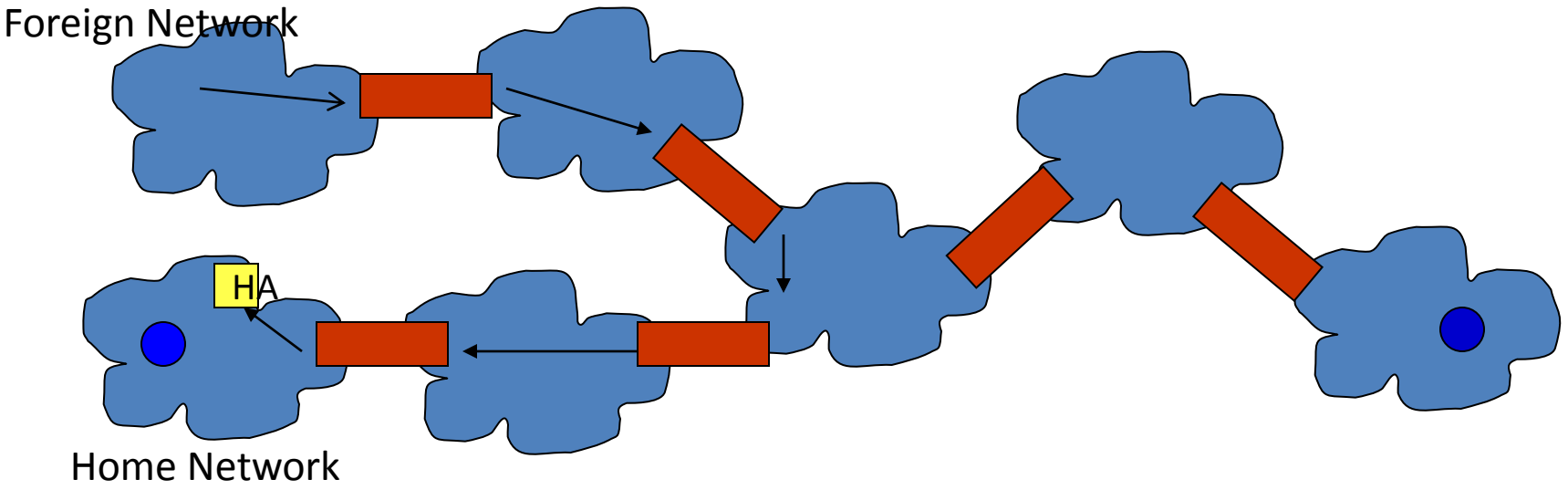
- Mobile node sends ICMP "Home Agent Address Discovery Request" request message to "Mobile IPv6 Home Agents" anycast address in its home network.
- Router acting as home agent responds with an ICMP "Home Agent Address Discovery Reply" message.
- Binding Update message: Visiting mobile node sends its primary care-of address to its home agent.
- Home agent responds with a Binding Acknowledgment message.
- Dynamic home agent discovery useful when home network gets reconfigured or old home agent is no longer in the network.

Move Detection

- Network-prefix-based:
  - Mobile node detects a change in the on-link subnet prefix
  - This indicates move to a new subnet.

Registration

- Mobile node moves into foreign network.
- Node sends registration message to HA.
- HA sends registration response, containing outcome (granted or denied) to mobile node.



Registration Reply

- Indicates whether registration request has been granted, or denied by home agent.
- Format similar to request message.
- Lifetime field indicates duration for which registration has been granted.
  - Once request issued, no node can increase the duration of the lifetime field.
  - Home agent can grant request for duration less than requested lifetime.

Determining Registration Duration

- Mobile node requests registration for T time units.
- Positive response received after time t.
- Let value of received lifetime = T'.
- If T=T', remaining registration lifetime = T-t.
- If T>T', remaining registration lifetime = T'-t.

Packet Delivery

- Address resolution: determining the hardware address of the node to which a packet has to be delivered.
- Tunneling: forwarding packet(s) to care-of address.
- Decapsulation: delivering packet to mobile node in its current network.

Address Resolution

- HA sends Neighbor Discovery advertisements to All-nodes multicast address:
  - Source address: IPv6 address of HA
  - Target IP address: IPv6 address of mobile node
  - Target Link-Layer address: link-layer address of HA
  - Router Flag (R-flag): 0
  - Override Flag (O-flag): set
- HA responds to Neighbor Solicitations for mobile node's IPv6 address.
- HA *Defends* mobile node's home address during Duplicate Address Detection.

Bidirectional Tunneling: IPv6 Encapsulation

- HA intercepts packet destined to mobile node's home address and decrements hop limit by 1.
- If hop limit > 0, encapsulate in IPv6 packet:
  - Source address of tunnel IP header = HA's IPv6 address.
  - Destination address = mobile node's primary care-of address.
- Path from HA to decapsulator is one logical hop.

Reverse Tunneling

Scenario: Packets sent by visiting node X to another node Y.

Source address in packets: Home address of X.

Ingress Filtering: Examination of the packet source address by router, and discarding the packet if source address seems to be topologically "incorrect."

Reason for ingress filtering?

Solution: Tunnel packets from mobile node to home agent, and then forward them to destination (correspondent node).

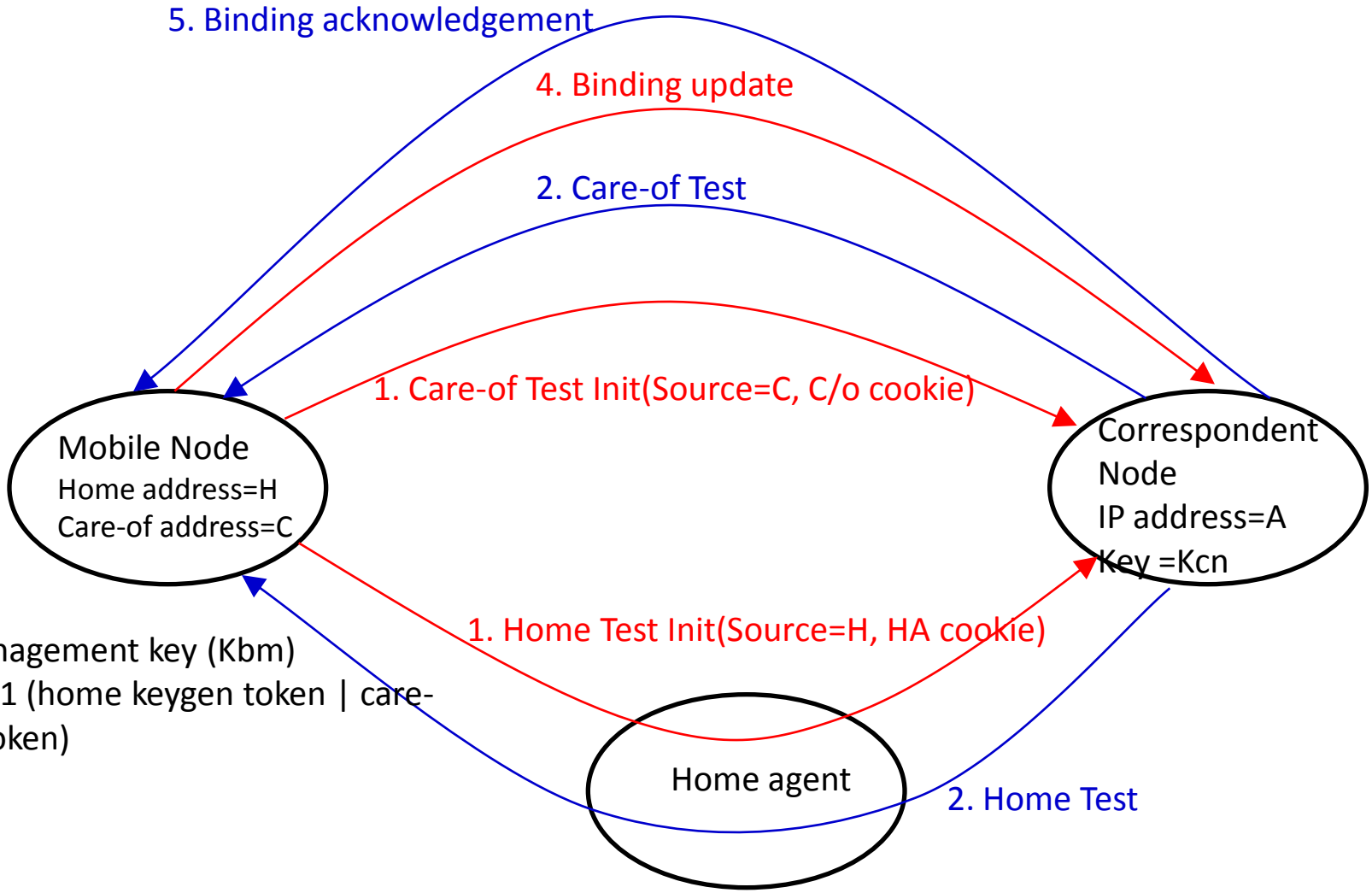
Reverse Tunneling (contd.)

- Forward tunnel: starts at the home agent and terminates at the mobile node's care-of address.
- Reverse tunnel: starts as the mobile node's care-of address and terminates at the home agent.

Communication with Correspondent Node

- Scenario: Mobile node receives a packet sent by a correspondent node such that:
  - The packet was tunneled using IPv6 encapsulation.
  - Destination address in the outer header is equal to the mobile node's care-of address.
  - Destination address in the inner header is the mobile node's home address.
  - Source addresses in the headers are different.
- Indication: Original sender of the packet (correspondent node) does not know current care-of address of the mobile node.
- Mobile node should send Binding Update message to correspondent node with its current care-of address.
- Correspondent node sends packets directly after that.

Care-of Test = (C/o cookie, Care-of keygen token, index_j)
Care-of keygen token = First(64, HMAC_SHA1(Kcn, (C | $nonce_j$ | 1)))



Home Test = (HA cookie, home keygen token, index_i)
Home keygen token = First(64, HMAC_SHA1(Kcn, (H | $nonce_i$ | 0)))

Route Optimization

- Mobile node constructs packets with:
  - Source address = care-of address in foreign network
  - Destination address = correspondent node's IPv6 address
  - Home address option field = home address of mobile node.
- Correspondent node sends packets with *Type 2 Routing header*:
  - Source address = correspondent node's IPv6 address.
  - Destination address = mobile node's care-of address.
  - Final destination (last hop) = mobile node's home address.
  - Processing of last hop: internal to mobile node.

On Returning to Home Network

- Mobile Node sends Binding Update to HA:
  - Source address = node's home address.
  - Acknowledgment (A) and Home Registration (H) bits set.
  - Lifetime = 0
  - Care-of address = Home address
- HA no longer acts as proxy for mobile node.

6LoWPAN: IPv6 over IEEE 802.15.4

Motivation

- Enable IPv6 to run over a network of wireless, low power personal area networks.
- Provides an adaptation layer between link and network layers.
- Use link and adaptation layer information to compress network and transport layer headers.

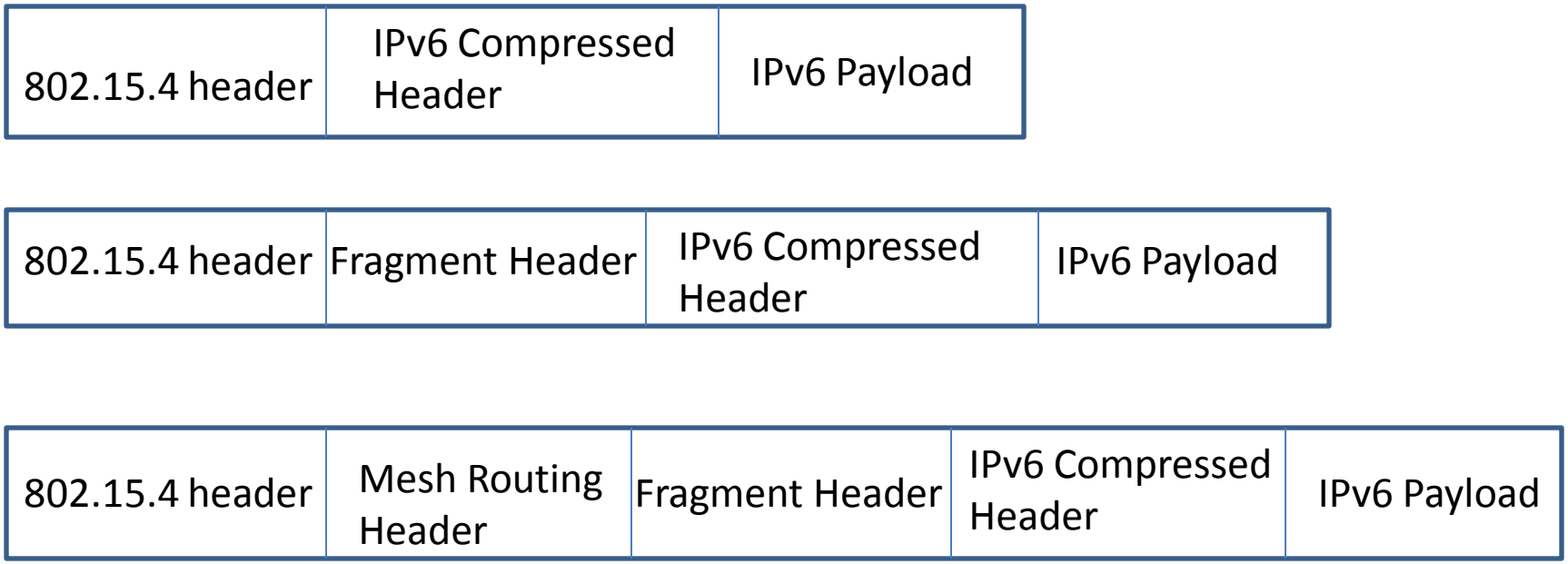
Problem

- Minimum IPv6 MTU requirement = 1280 bytes.
- IPv6 fragmentation: only at endpoints.
- IEEE 802.15.4:
  - Maximum frame length = 128 bytes
  - Link-layer payload may be limited to 81 bytes
  - Max throughput = 250 kbps
  - Limited buffering and processing capability at nodes.

6LoWPAN Adaptation Layer

- Header compression when information can be retrieved using shared context or link-layer information:
  - Compressed fields
  - Elided fields.
- Fragmentation into multiple link-layer frames.
- Layer-two, mesh forwarding.

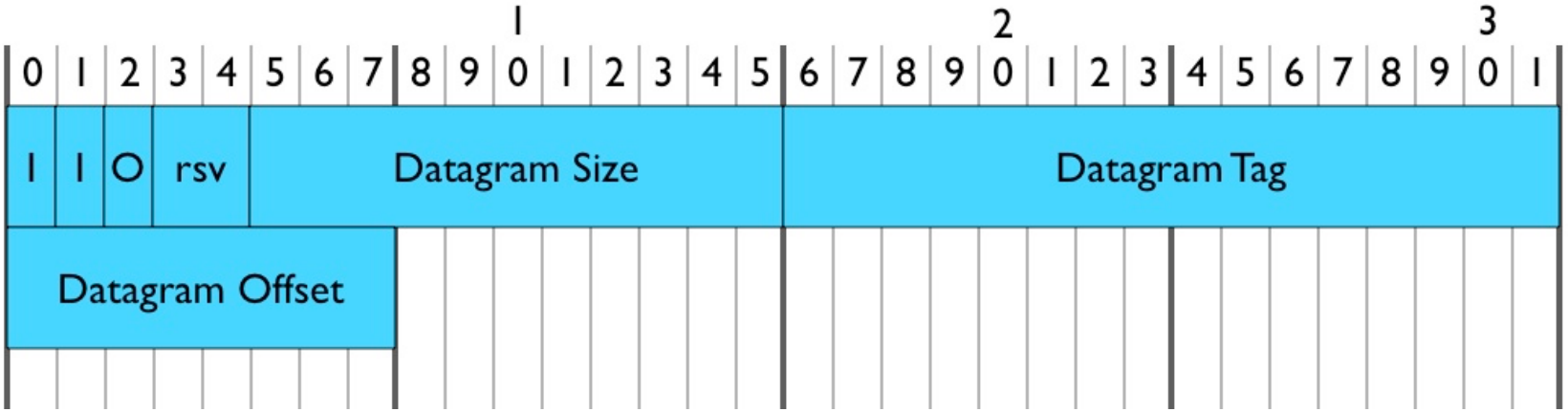
6LoWPAN Header Stacking



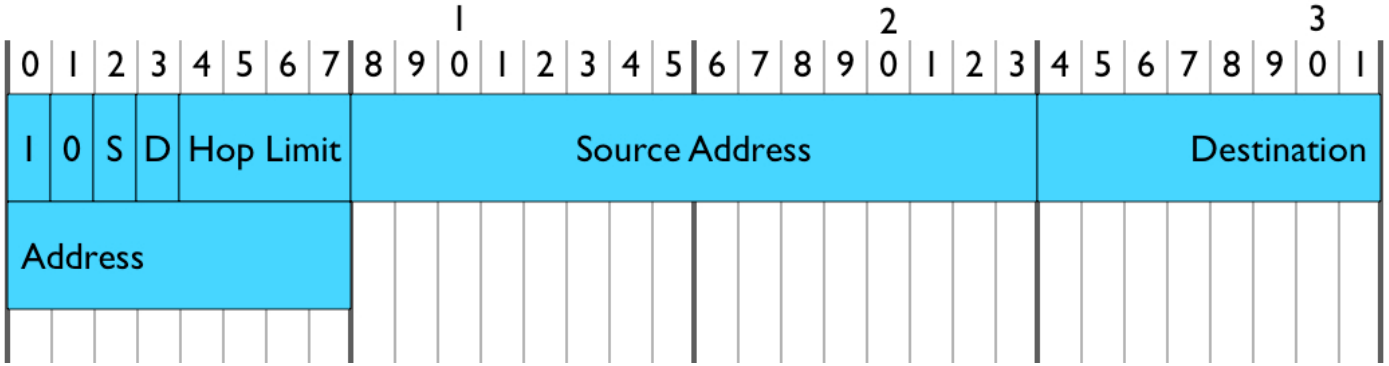
From: 6LoWPAN: Incorporating IEEE 802.15.4 into the IP architecture; Internet Protocol for Smart Objects (IPSO) Alliance White paper # 3, Jonathan Hui, David Culler, Samita Chakrabarty

Fragment Header (4 or 5 bytes)

- Datagram size: of unfragmented payload
- Datagram tag: same for all fragments of a payload
- Datagram offset: position of fragment in unfragmented payload (in multiples of 8 bytes)

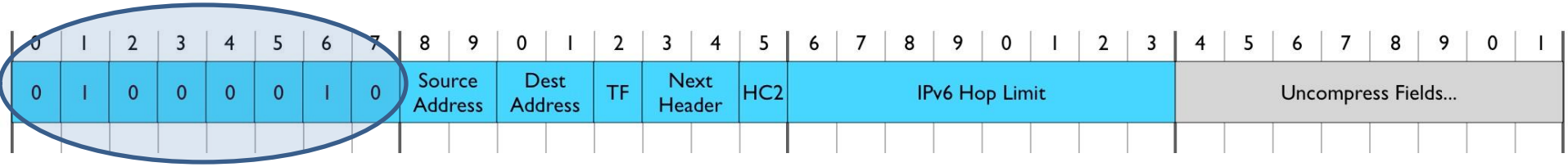


Mesh Routing Header (5-17 bytes)



- Supports multi-hop, layer two forwarding.
- End-points of an IP hop (extended or short address):
  - Source address
  - Destination address
- Hop limit: decremented with each hop.
  - Frame discarded if 0.
  - S, D: indicate short or extended source, destination address, respectively.

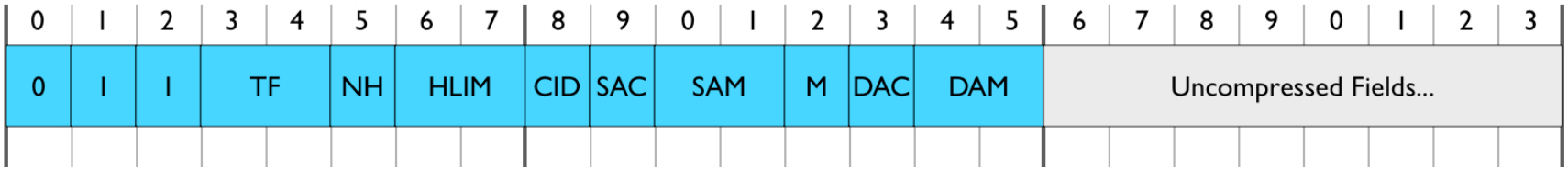
IPv6 Header Compression (3 bytes!)



Dispatch: HC1 used

- 64-bit network prefix compressed to 1 bit for source and destination address when they correspond to link local prefix.
- 64-bit source and destination interface identifiers elided if derivable from link layer addresses or Mesh Routing Header.
- Traffic class and flow label compressed to single bit, if both zero.
- Next header = 2 bits, if TCP, UDP or ICMPv6.
- Payload length elided:
  - Can be derived from IEEE 802.15.4 frame or Fragment Header.
- Not very useful for communication using global IPv6 addresses.

Improved IPv6 Header Compression



- Up to 16 shared contexts to compress external source or destination prefix.
- TF: traffic type and flow label separately compressed.
- HLIM: if hop limit 1 or 255 and compressed, or carried inline.
- CID: context identifier (0=default)
- SAC/DAC: whether stateless (link local) or context-based compression of source/destination address employed.
- SAM/DAM: whether full source/destination address is carried inline, upper 16 or 64 bits elided, or full address elided based on context.
- M: whether destination address is unicast or multicast.

Conclusion

- Mobile IPv6 supports communication by nodes on the move.
- Return routability operations result in efficient forwarding of packets between mobile node and correspondent node.
- 6LoWPAN helps reduce runs IPv6 over IEEE 802.15.4 personal area networks.