6LoWPAN

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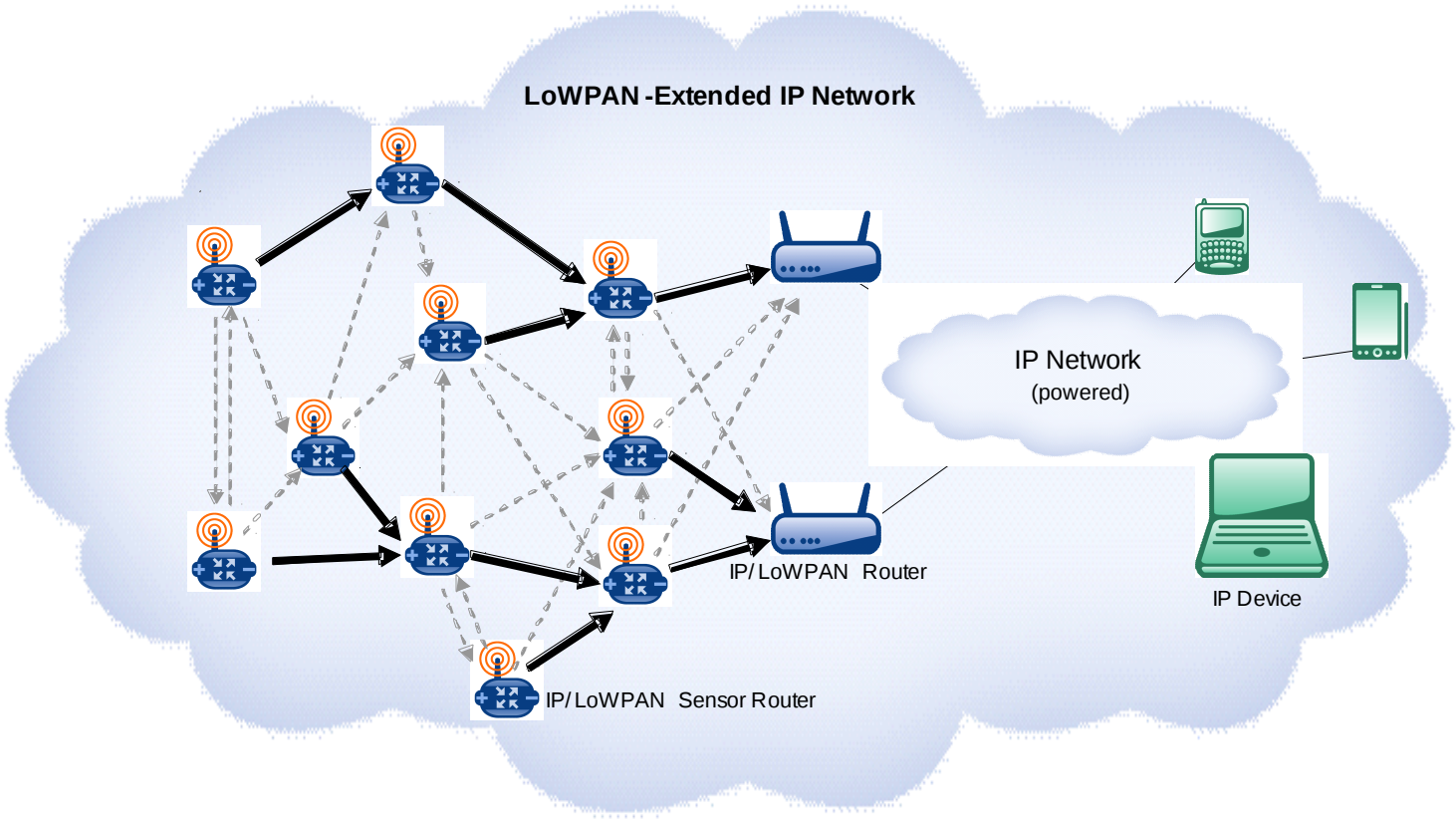
November 30th, 2010

6LoWPAN … what it means for smart objects

- Low-Power Wireless Embedded devices can now be connected using familiar networking technology,
  - like ethernet (but even where wiring is not viable)
  - and like WiFi (but even where power is not plentiful)
- All of these can interoperate in real applications
- Interoperate with traditional computing infrastructure
- Utilize modern security techniques

- Application Requirements and Capacity Planning dictate how the network is organized,
  - not artifacts of the underlying technology

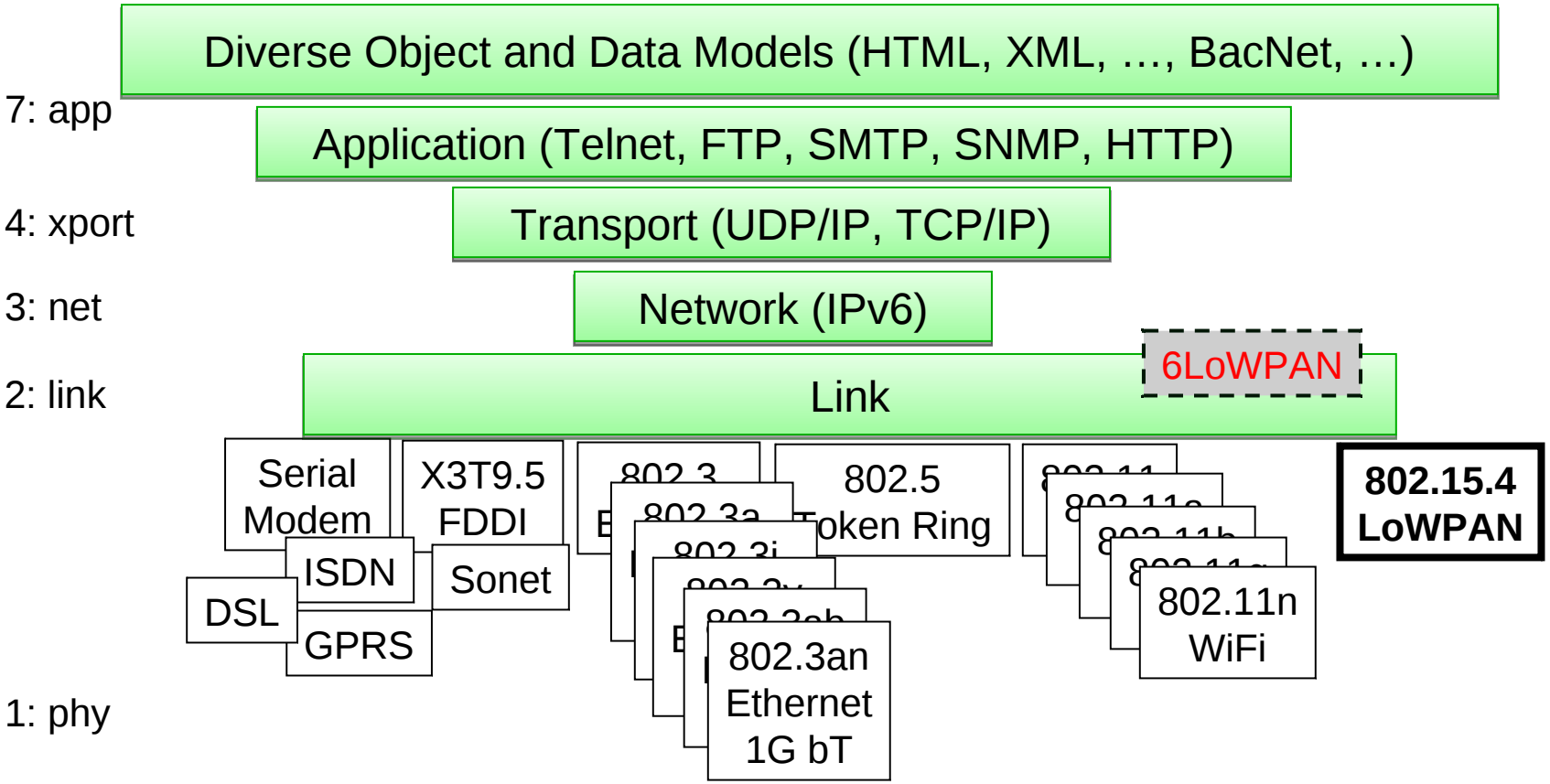
Low Power Wireless Internet



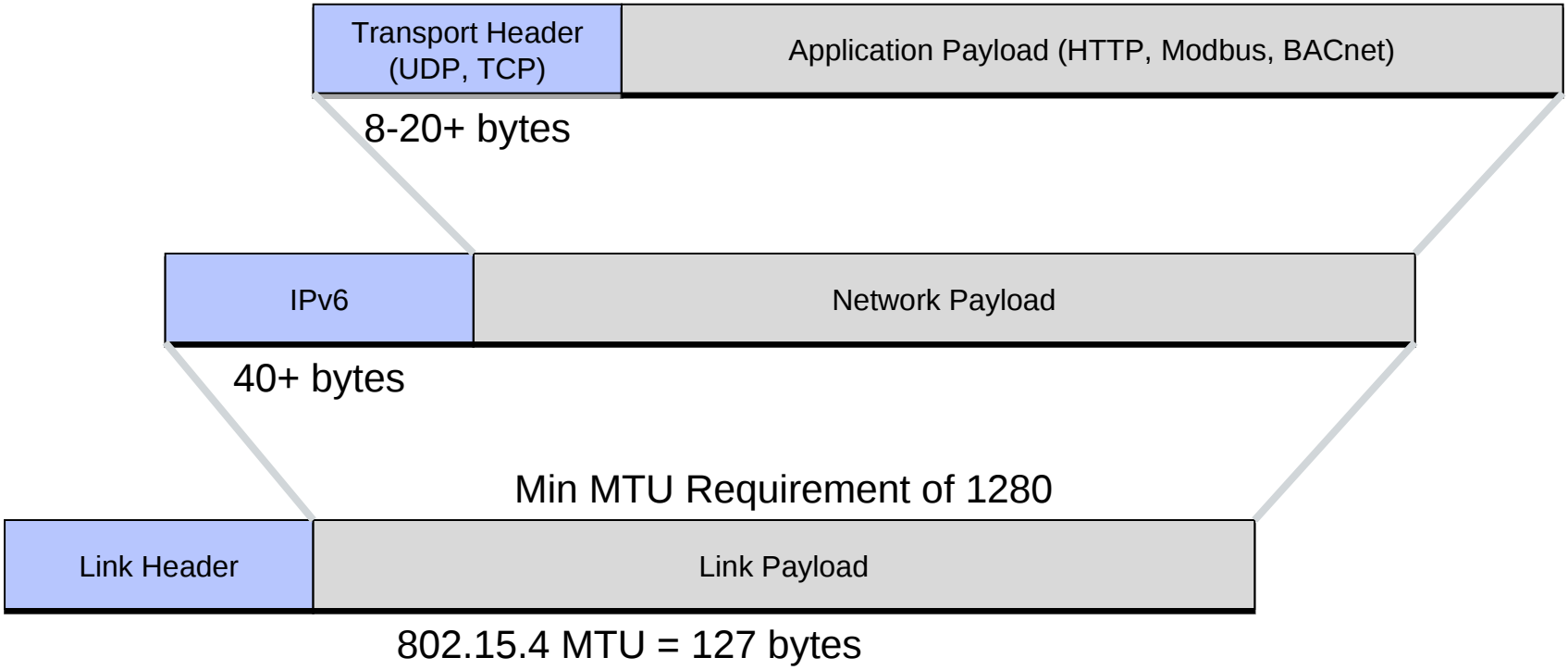
Wireless links

	802.15.4	802.15.1	802.15.3	802.11	802.3
Class	**WPAN**	**WPAN**	**WPAN**	**WLAN**	**LAN**
Lifetime (days)	**100-1000+**	**1-7**	**Powered**	**0.1-5**	**Powered**
Net Size	**65535**	**7**	**243**	**30**	**1024**
BW (kbps)	**20-250**	**720**	**11,000+**	**11,000+**	**100,000+**
Range (m)	**1-75+**	**1-10+**	**10**	**1-100**	**185 (wired)**
Goals	**Low Power, Large Scale, Low Cost**	**Cable Replacement**	**Cable Replacement**	**Throughput**	**Throughput**

6LoWPAN is an Adaptation Layer



6LoWPAN – Adaptation Needs

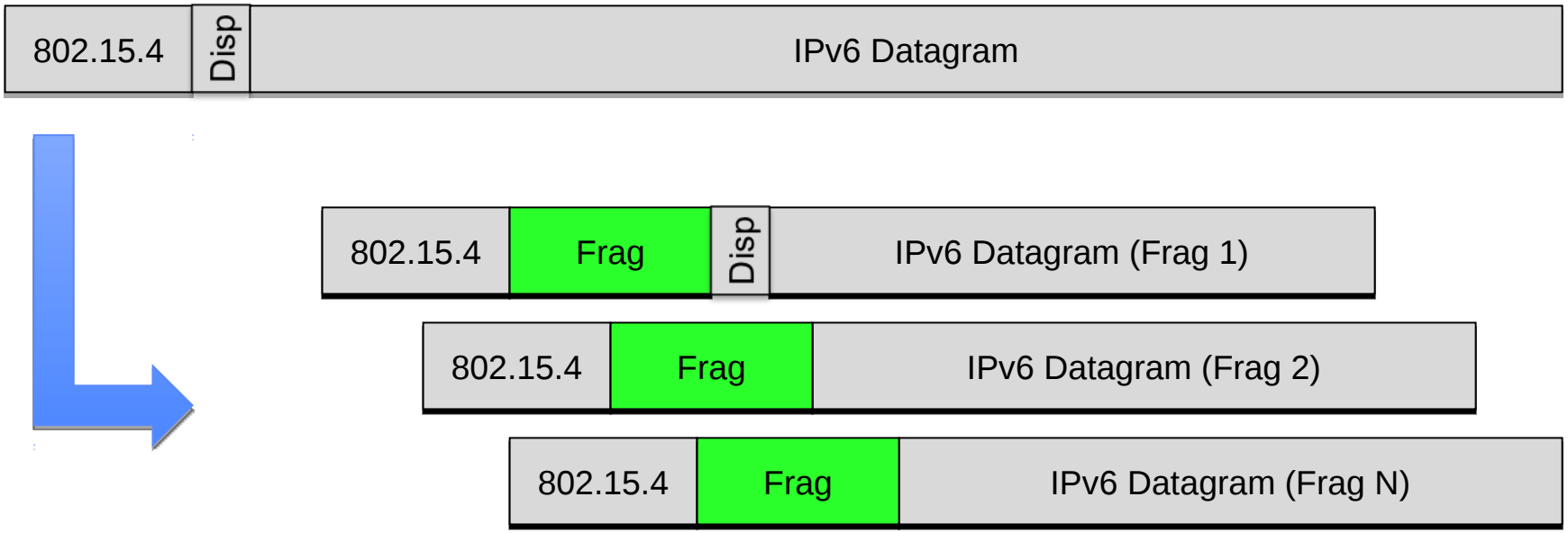


- Minimum MTU >> 802.15.4 MTU ➔ Fragmentation
- 48+ byte UDP IPv6 Header ➔ Header Compression
- Defines a Chained Header format via Dispatch
  - Analogous to IPv6 Header stack

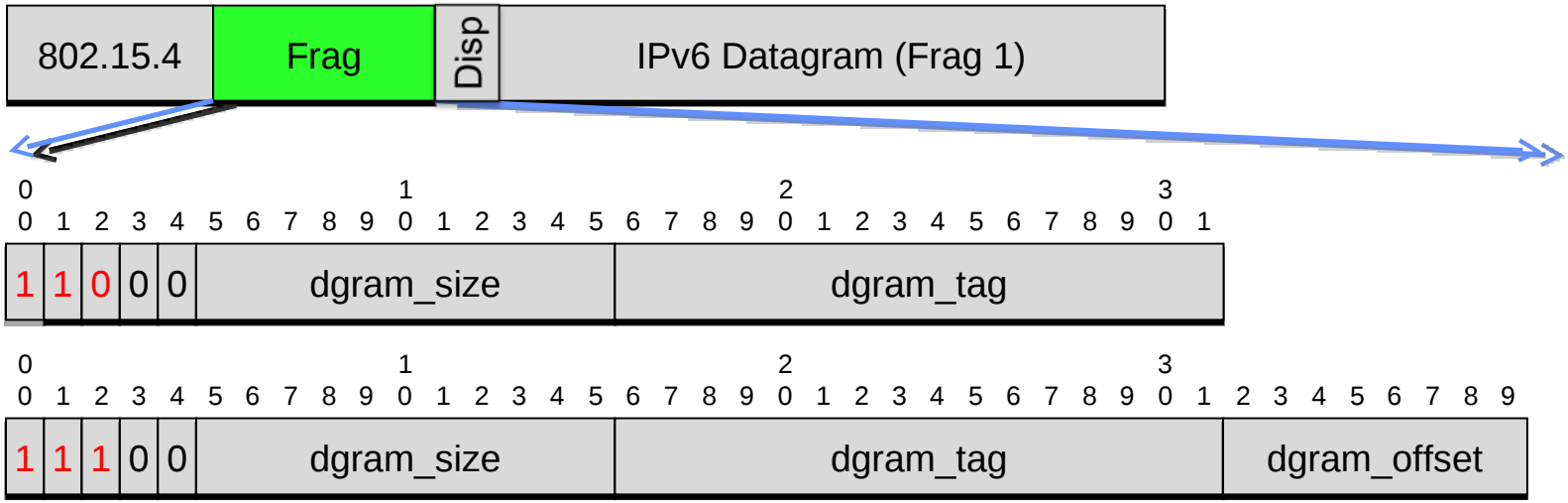
6LoWPAN Fragmentation

- 802.15.4-2006 has a link MTU of 127 bytes
- IPv6 requires a min link MTU of 1280 bytes

  ➔ 6LoWPAN must provide fragmentation

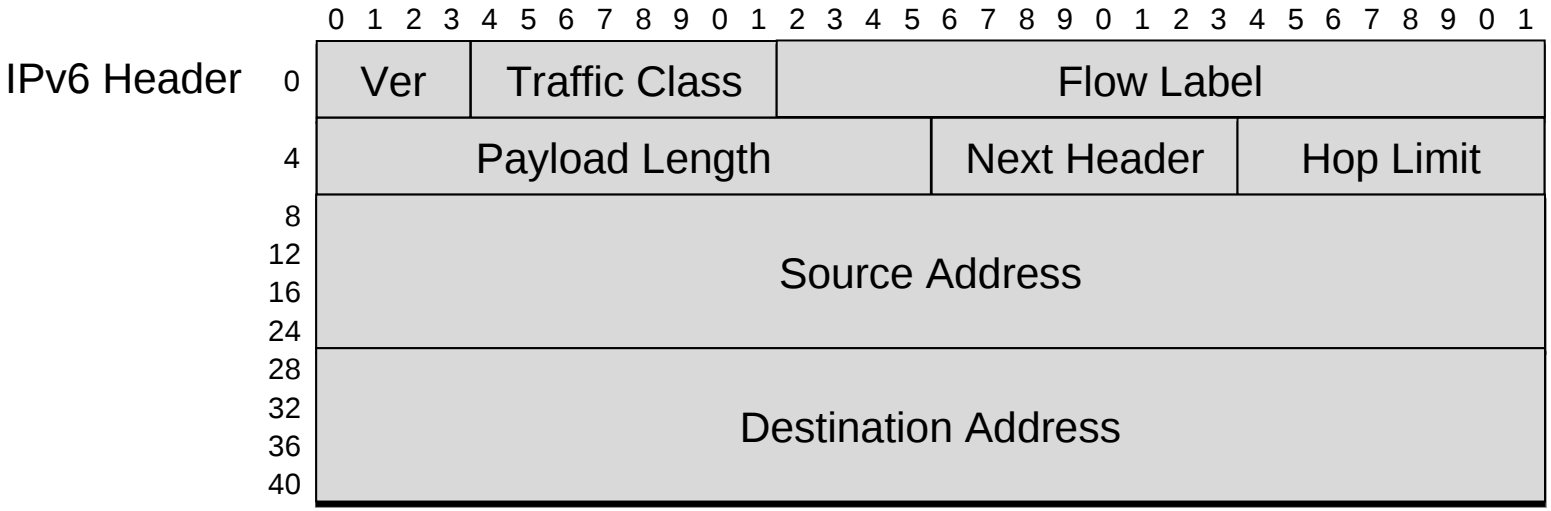


6LoWPAN Fragmentation



- Size: size of datagram in bytes
  - Included in all fragments to simplify buffer allocation
- Tag: identifies all fragments of a datagram
- Offset: location of fragment in 8-byte units
  - Elided in first fragment

6LoWPAN Header Compression



- Use little state and do no depend on flows
- Common values for header fields => compact forms
  - Version is always 6
  - Traffic Class and Flow Label are zero
  - Payload Length always derived from L2 header
  - Source and Destination Addrs are link-local and derived from L2 addrs

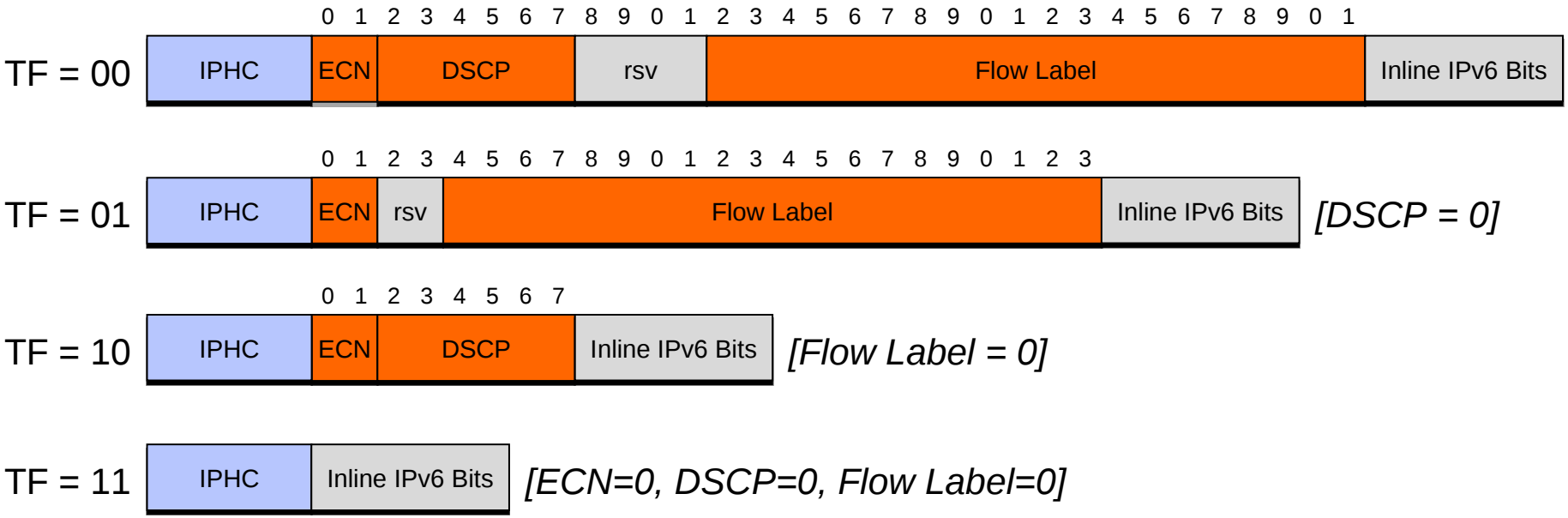
IPv6 Header Compression

0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	
0	**1**	**1**	TF		NH	HLIM		CID	SAC	SAM		M	DAC	DAM		In-line IPv6 Header Bits

- TF (Traffic Class and Flow Label)
  - 0: Carried Inline (ECN+DSCP+Flow), 1: ECN+Flow, 2: ECN+DSCP, 3: All zero
- NH (Next Header compression)
  - 0: Carried Inline, 1: Next Header is compressed
- HLIM (Hop Limit = Inline, 1, 64, 255)
  - 0: Carried Inline, 1: 1, 2: 64, 3: 255
- CID (Context Identifier Extension)
  - 0: No 1-byte CID identifier, 1: 1-byte identifier follows
- SAC/DAC (Source/Destination Address Compression)
  - 0: Stateless, 1: Context-based
- SAM/DAM (Source/Destination Address Mode)
  - 0: 16 bytes inline, 1: 8 bytes inline, 2: 2 bytes inline, 3: elided
- M (Multicast Destination)
  - 0: Destination is not multicast, 1: Destination is multicast

6LoWPAN Header Compression

- **Traffic Class and Flow Label**



6LoWPAN Header Compression

- **Next Header**

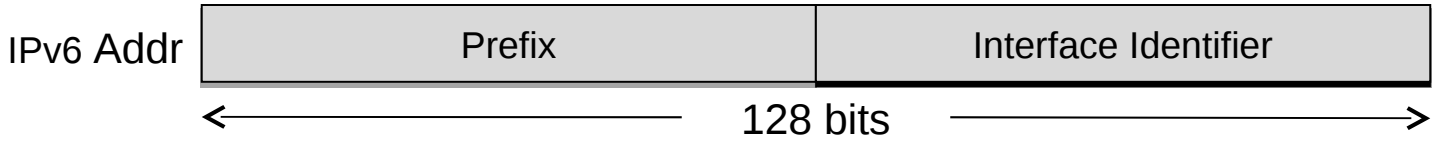
NH = 0	IPHC	Inline IPv6 Bits	Next Header	Inline IPv6 Bits	Uncompressed Next Header
NH = 1	IPHC	Inline IPv6 Bits	Inline IPv6 Bits	NHC	Uncompressed Next Header

- **Hop Limit**

HLIM = 00	IPHC	Inline IPv6 Bits	Hop Limit	Inline IPv6 Bits	
HLIM = 01	IPHC	Inline IPv6 Bits			*[Hop Limit = 1]*
HLIM = 10	IPHC	Inline IPv6 Bits			*[Hop Limit = 64]*
HLIM = 11	IPHC	Inline IPv6 Bits			*[Hop Limit = 255]*

6LoWPAN Header Compression

- **IPv6 Unicast Address**

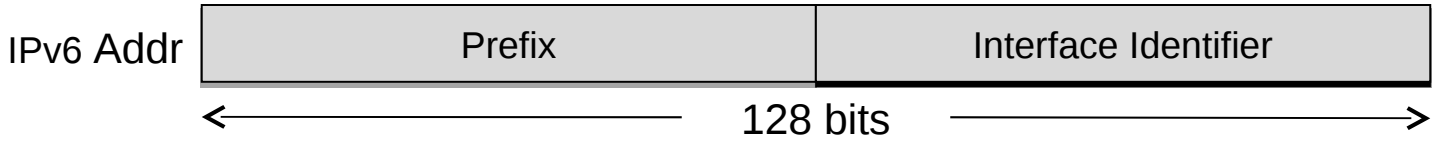


- Prefix
  - Addrs within 6LoWPAN typically contain common prefix
  - Nodes typically communicate with one or few central devices
  - Establish state (contexts) for such prefixes – only state maintenance
  - Support for up to 16 contexts

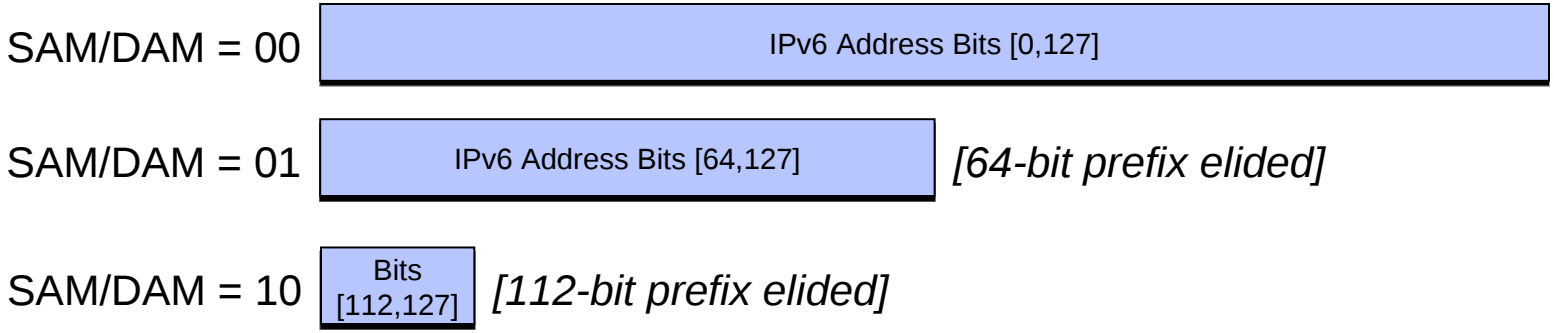
- Interface Identifier
  - Typically derived from L2 addr during autoconfiguration
  - Elide when Interface Identifier can be derived from L2 header

6LoWPAN Header Compression

- **IPv6 Unicast Address**



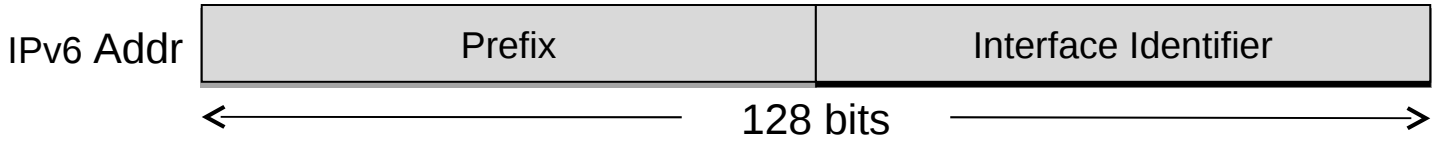
- **Source/Destination Address Mode**



SAM/DAM = 11 *[Full 128-bit address elided, IID derived from link-layer]*

6LoWPAN Header Compression

- **IPv6 Unicast Address**

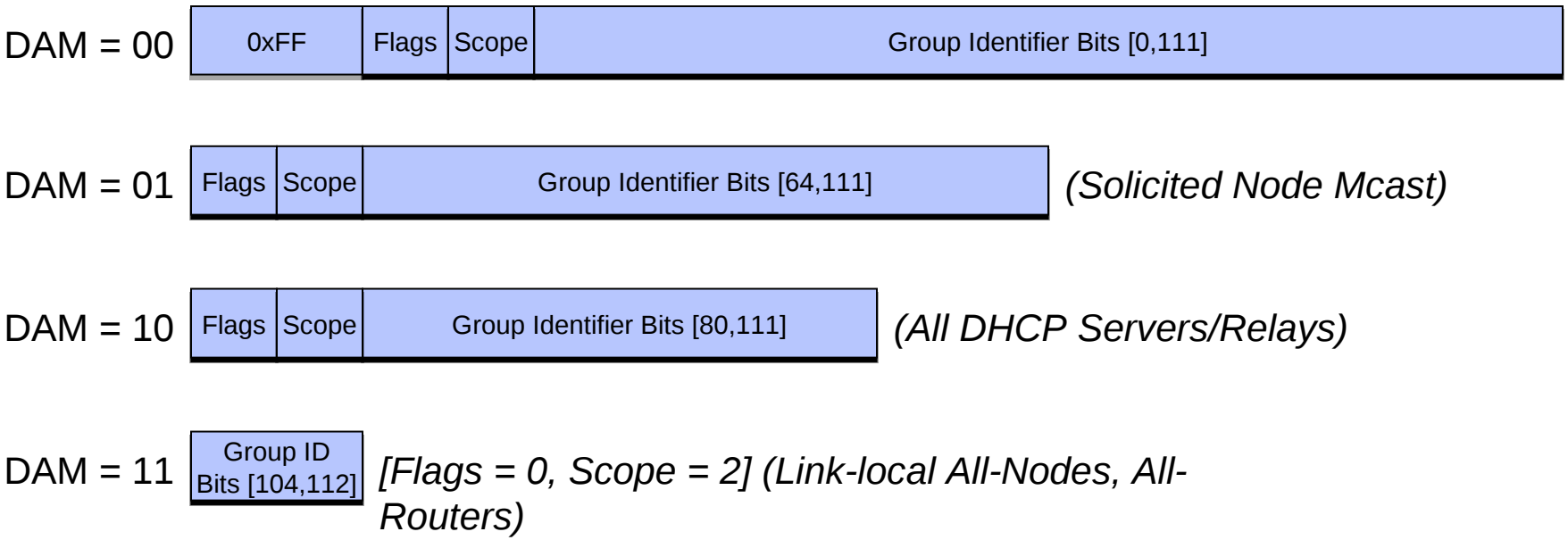


- **IPv6 Prefix**

- Stateless Mode (SAC/DAC=0)
  - Prefix is link-local (fe80::/10)
- Context-based Mode (SAC/DAC=1)
  - Prefix taken from stored contexts (up to 16 contexts)
  - CID = 0, use ContextID = 0
  - CID = 1, include 4-bit ContextID for source & destination

6LoWPAN Header Compression

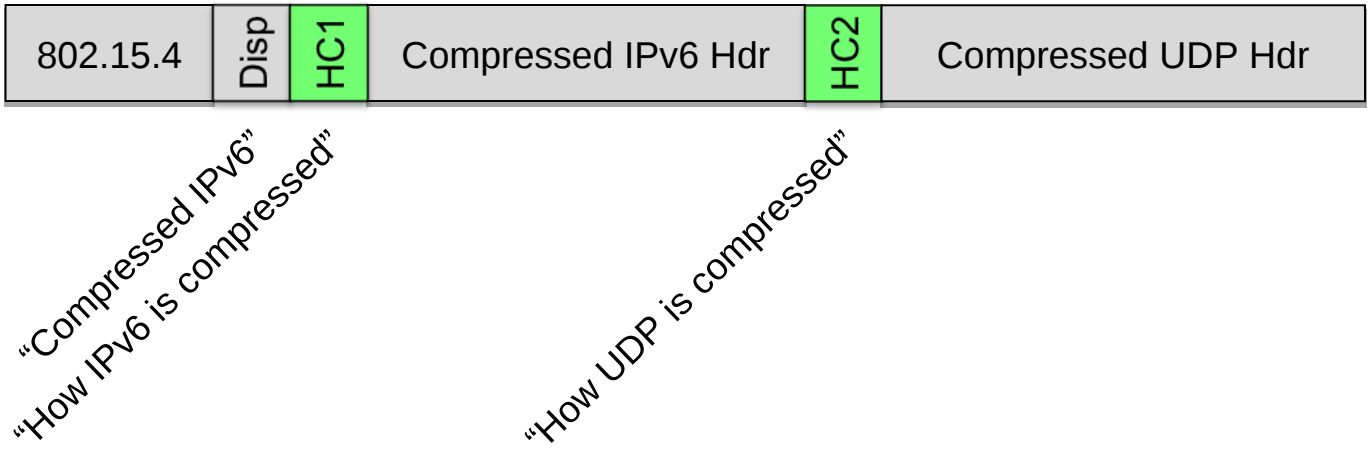
- **IPv6 Multicast Address**
  - GroupIDs typically consume a small number of bits



6LoWPAN Header Compression

- Each compressed header indicates if the next header is also compressed

- Following control byte(s) include next header identifier
  - ➔ Framework for defining arbitrary Next Header compression methods



6LoWPAN Header Compression

- **UDP Header**

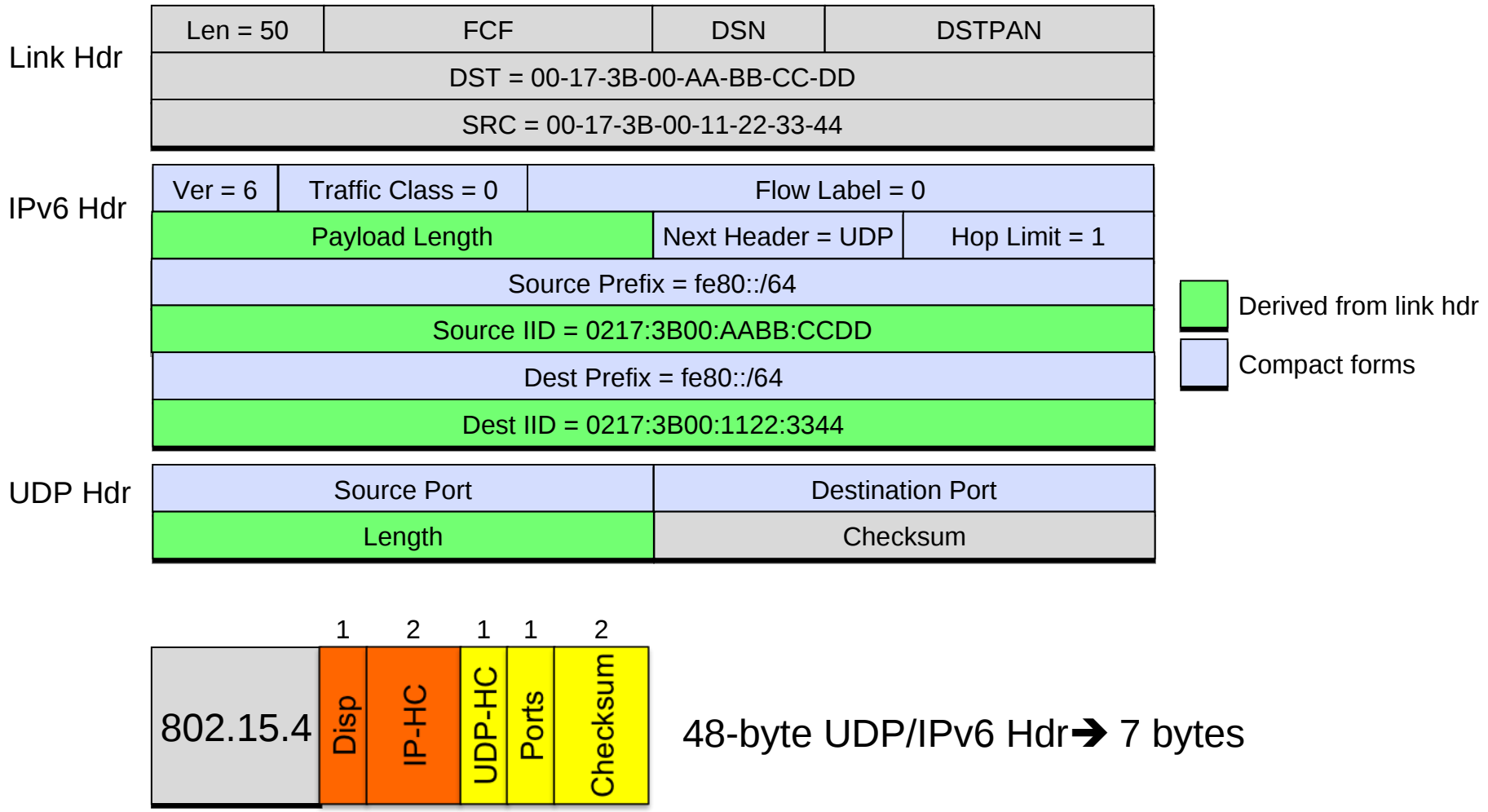
	0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5	6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
0	Source Port	Destination Port
4	Length	Checksum

- Assume common values for header fields and define compact forms
  - Ports within 61616 to 61632 (4 bits)
  - Length derived from IPv6 Length
  - Checksum may be elided if other integrity checks are in use (e.g. Ipsec)
- No definition for TCP or ICMPv6

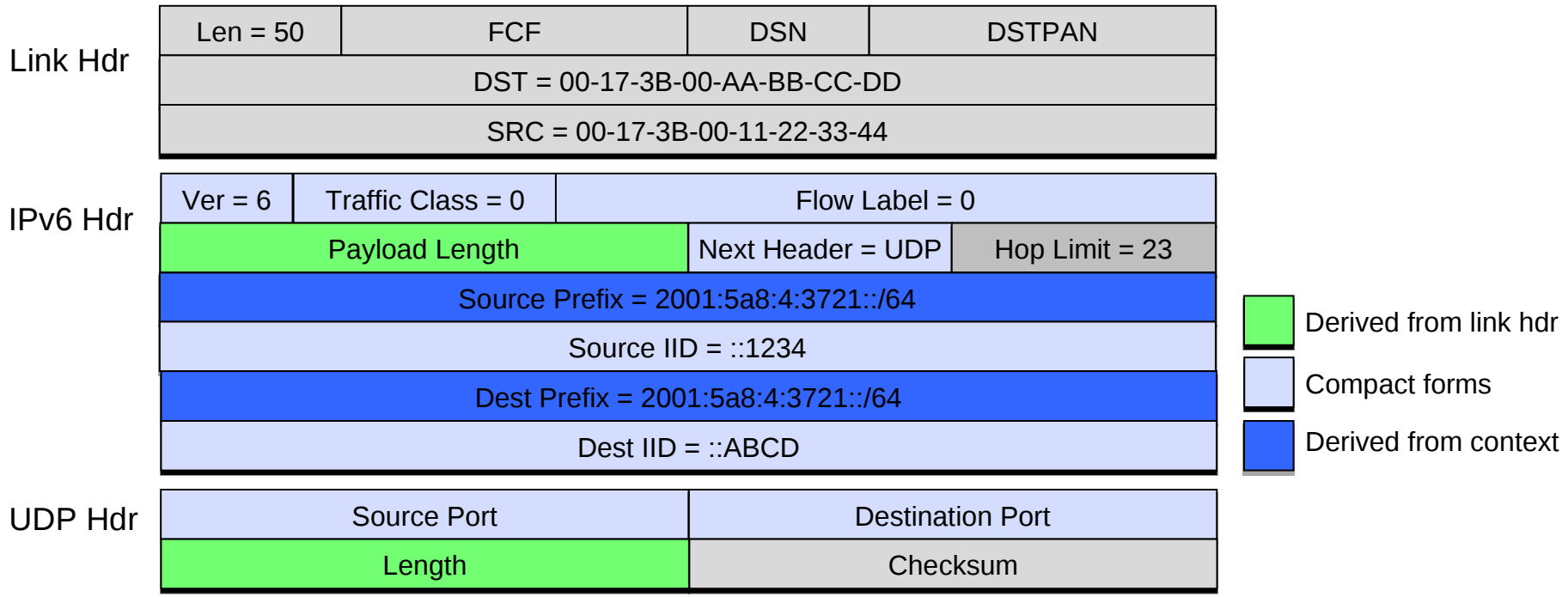
0	1	2	3	4	5	6	7
1	1	1	1	0	C	P	

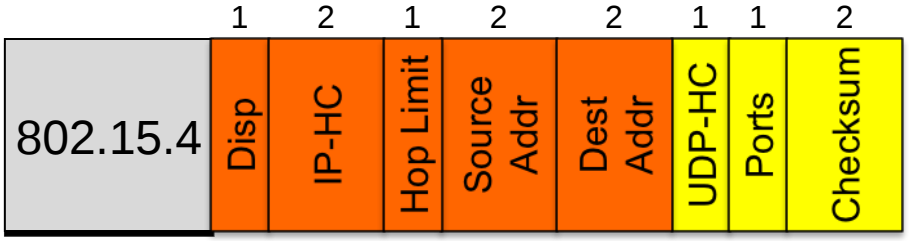
- C (Checksum): 0: Inline, 1: Elide
- P (Ports):
  - 0: Inline
  - 1: Elide first 8 bits of Dest Port
  - 2: Elide first 8 bits of Source Port
  - 3: Elide first 12 bits of Source and Dest Ports

Example: Link-Local Unicast



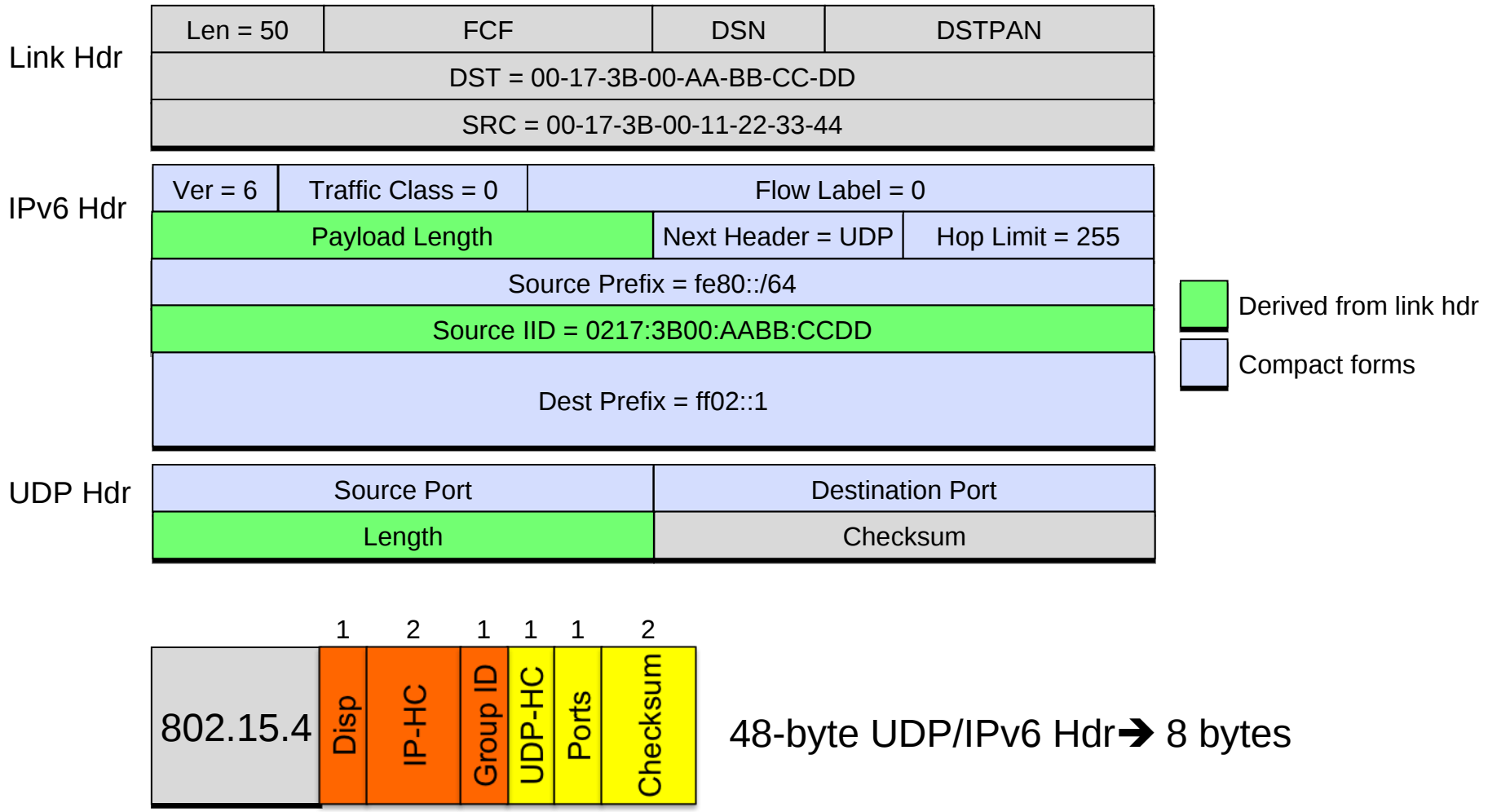
Example: Global Unicast





48-byte UDP/IPv6 Hdr ➔ 12 bytes

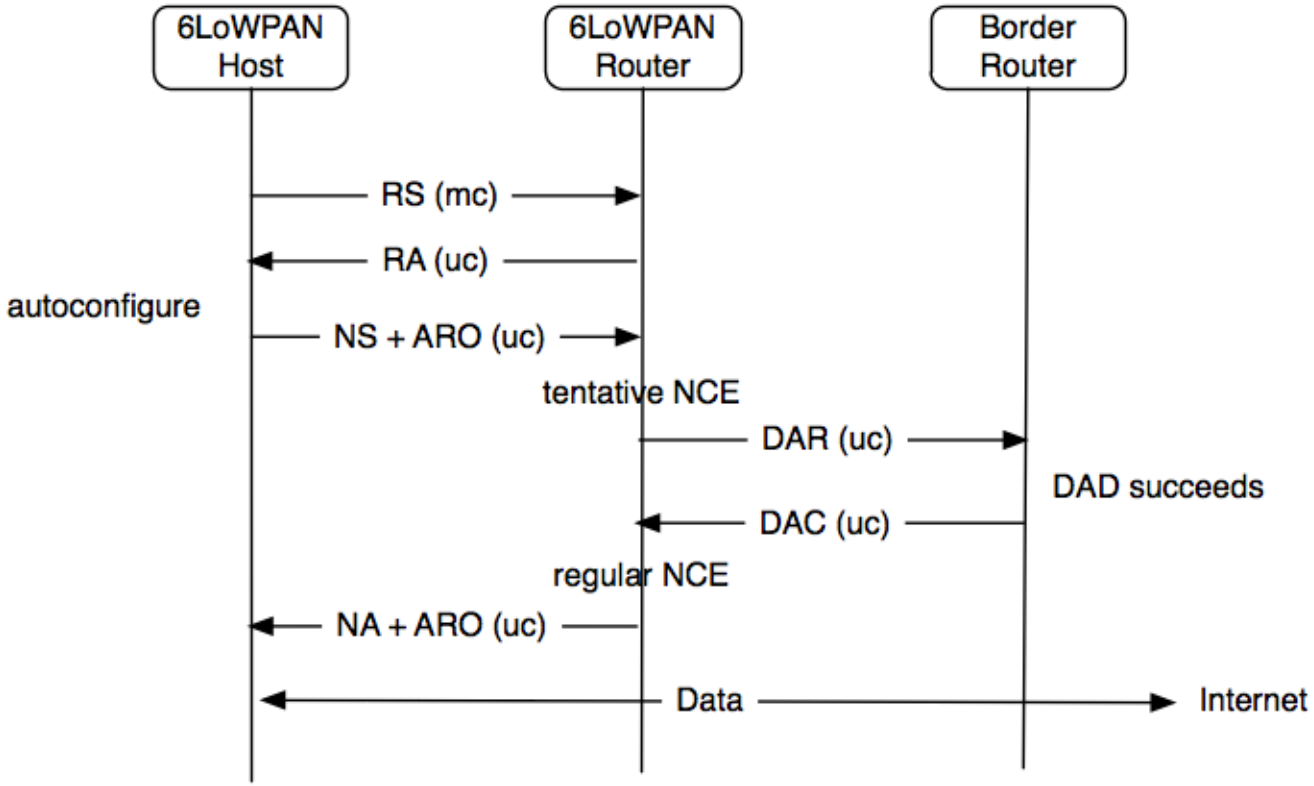
Example: Link-Local Multicast



Neighbor Discovery in 6LoWPAN

- IPv6 Neighbor Discovery defines [RFC4861]
  - How hosts discover routers and prefixes
  - How nodes resolve L2 addresses from IP addresses
  - How nodes perform unreachability detection
- But ND was originally designed for
  - LAN (e.g. Ethernet) connected interfaces
  - Always-on equipment such as PCs
- 6LoWPAN has unique requirements
  - Both single-hop mesh and multi-hop IP routed networks
  - Lossy and asymmetric radio environment
  - Frequent multicast traffic is expensive
  - Address resolution is not required
  - Unique EUI-64 addresses
  - Hosts may be sleeping to preserve energy

6LoWPAN ND at a Glance

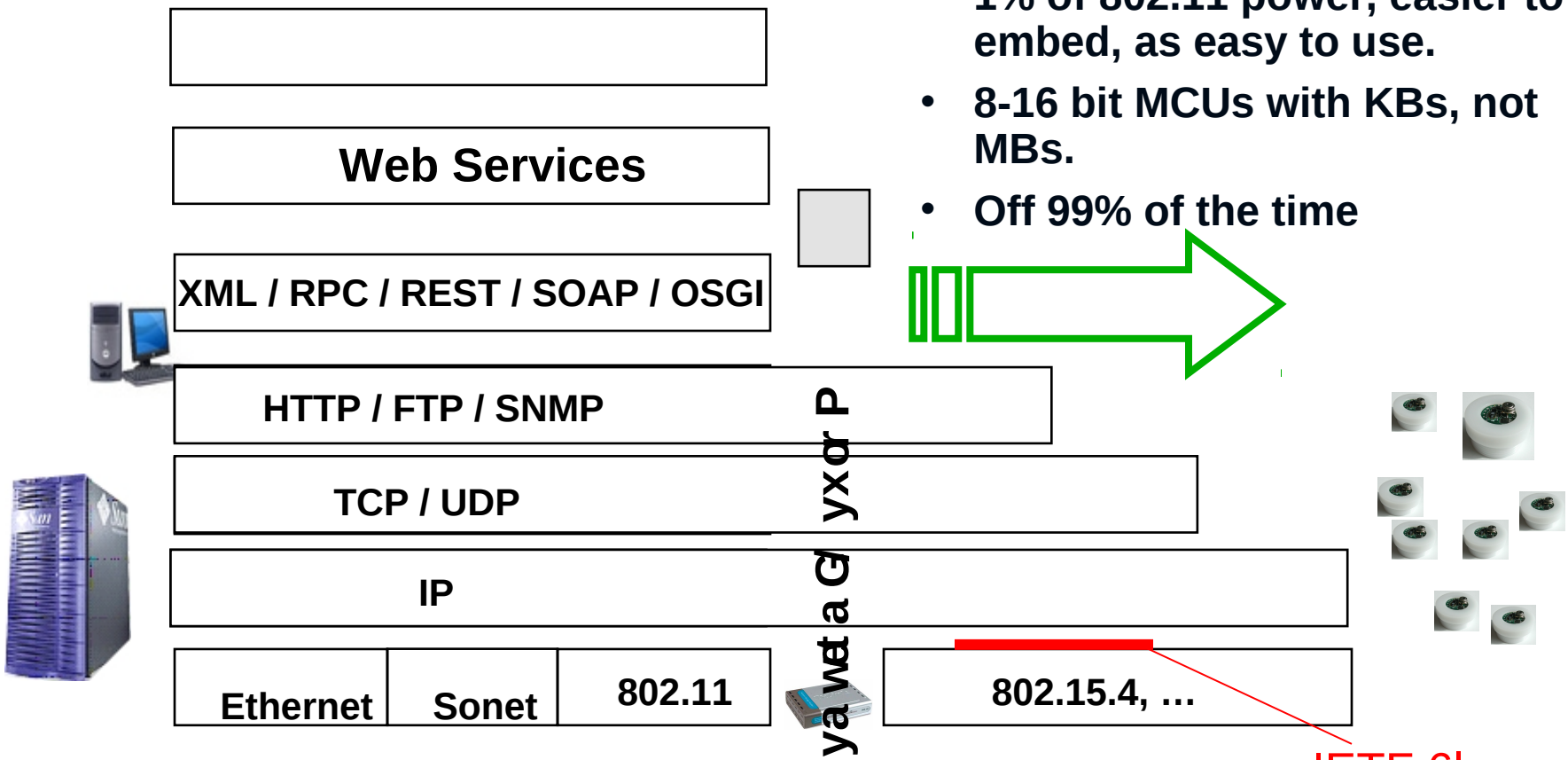


Legend:
(mc) = Multicast
(uc) = Unicast

LoWPAN in an IP Stack

LoWPAN – 802.15.4

- **1% of 802.11 power, easier to embed, as easy to use.**
- **8-16 bit MCUs with KBs, not MBs.**
- **Off 99% of the time**



Conclusion

- 6LoWPAN turns IEEE 802.15.4 into the next IP-enabled link
- Provides open-systems based interoperability among low-power devices over IEEE 802.15.4
- Provides interoperability between low-power devices and existing IP devices, using standard routing techniques
- Paves the way for further standardization of communication functions among low-power IEEE 802.15.4 devices
- Offers watershed leverage of a huge body of IP-based operations, management and communication services and tools
- Great ability to work within the resource constraints of low-power, low-memory, low-bandwidth devices like WSN