

Extending the Internet with TOSKI (TinyOS Kernel - IPv6)

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Schedule

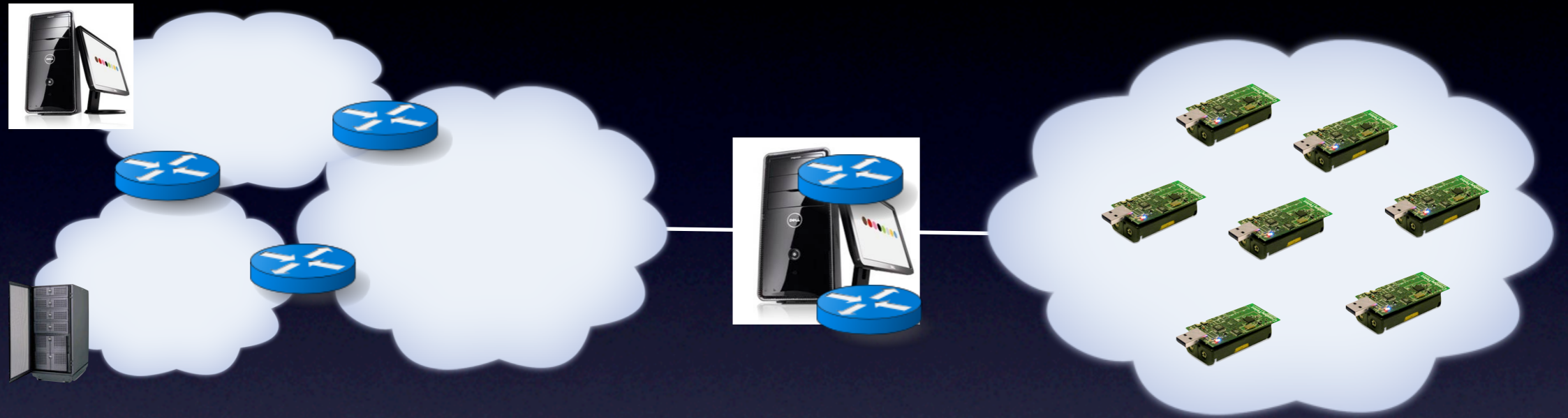
- **Brief Introduction to IPv6/6LoWPAN (20 min)**
 - *Sensor networking* (SerialForwarder vs. IP router)
 - IPv6 Essentials
 - Defining an IP link (route-over vs. mesh-under)
 - Delivering IPv6 datagrams (6LoWPAN adaptation)
 - TOSKI overview
- **Hands-on Tutorial (80 min)**
 - UDP (20 min)
 - TCP (20 min)
 - Telnet (20 min)
 - HTTP (20 min)
- **Open playtime/discussion (20 min)**

Sensor Networking Past



- Interconnect:
 - Bridge node, serial forwarder
 - Stateful application gateways
- Networking abstractions
 - Collection, dissemination
- No network architecture
 - No discovery, naming, addressing, configuration, and management

Sensor Internetworking



- **Interconnect: IP routers/egress points**
 - No application state - nodes communicate end-to-end with destination
 - Small number of egress - optimizations (e.g. proxy, cache, translation)
- **Networking abstractions**
 - Unicast, Multicast
- **Network architecture**
 - IP addresses, UDP/TCP ports, ICMPv6, ...

Introduction to IPv6



- IPv6 specified in 1998 - RFC 2460
- Goals of IPv6
 - Scalability
 - Unattended operation
 - Configurability and manageability
 - Flexibility and extensibility
- UDP and TCP largely unchanged

IPv6 Addressing

- 128 bits
 - Multiple IPv6 addresses for every grain of sand on the earth!
 - Types: Unicast, Multicast, Anycast

- Notation

- Unicast: 2001:0db8:85a3::5678
- Multicast: FF02::1 (link-local all-nodes)
- Prefix: 2001:0db8:85a3::/64

- Address Format



- Prefix: Identifies a subnet
- IID: Identifies a interface in the subnet - usually derived from L2 address

- Scopes

- Link-Local: interfaces within a single link only
- Global: interfaces anywhere in the Internet.

IPv4 Mapped Addresses

- IPv6 addresses can carry IPv4 addresses
 - ::ffff:192.168.0.1
 - ::ffff:c0a8:1
- Allows IPv6-only nodes to communicate with IPv4-only nodes
 - Stateless IP/ICMP Translation (SIIT)



Configuration & Management

- IPv6 Neighbor Discovery
 - Address resolution
 - Neighbor unreachability detection
 - Duplication address detection
 - Default route selection
- Stateless Address Autoconfiguration
 - Prefix advertised by router combined with L2-derived IID
- ICMPv6
 - Reachability
 - Availability
 - ...

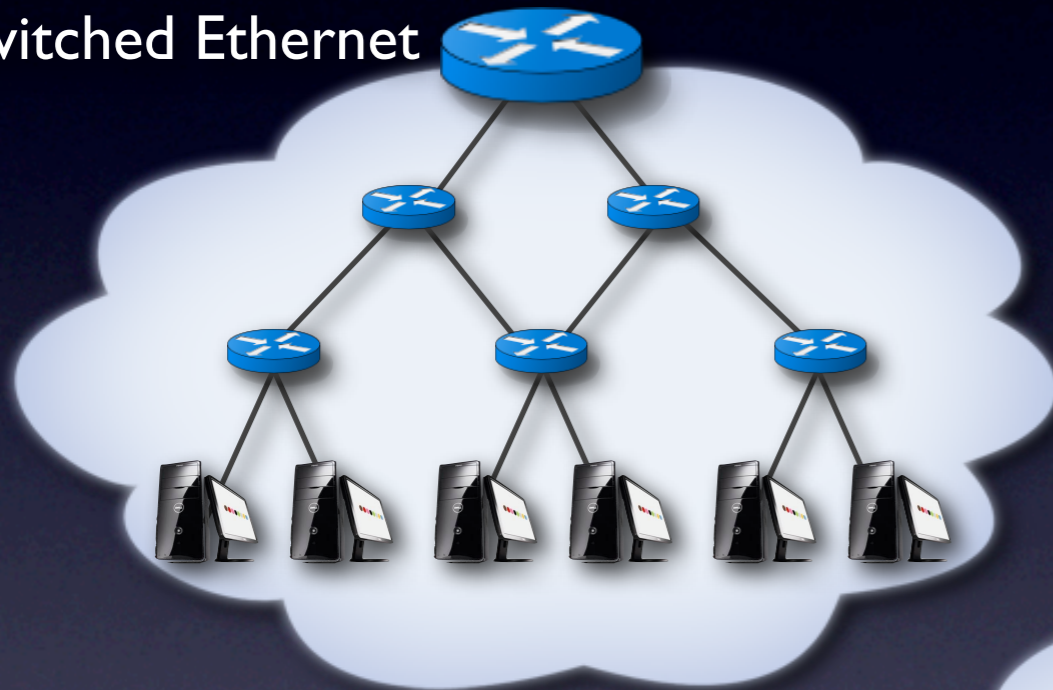
Building an IPv6 Sensornet

- Defining the IP link
- Delivering IPv6 datagrams

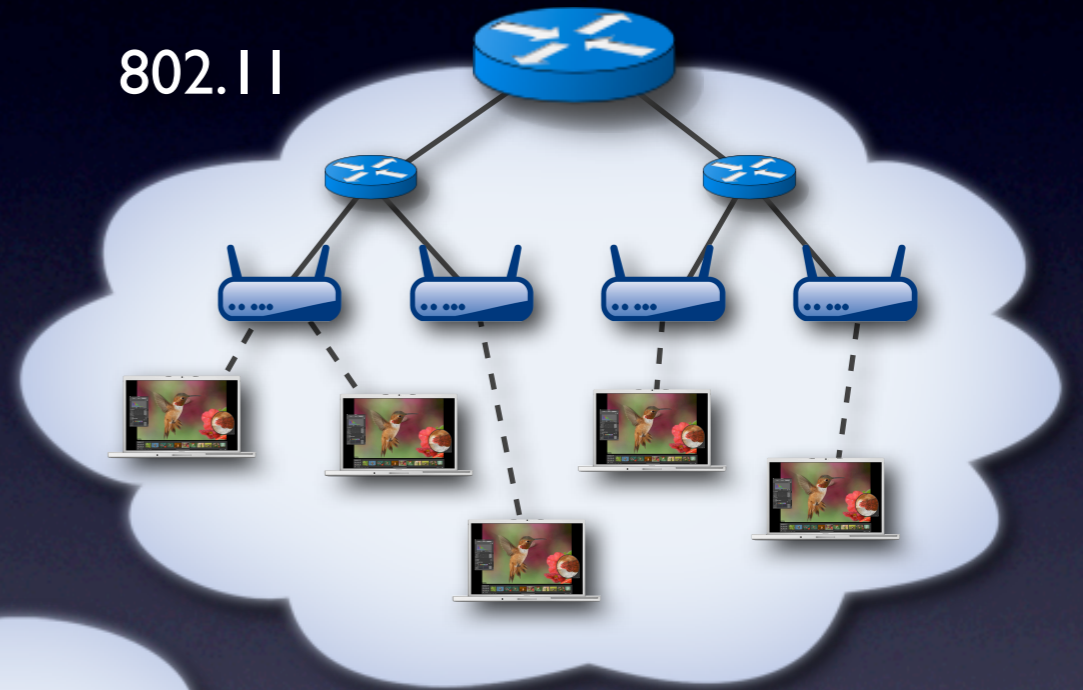
What is an IP link?

Nodes reachable by a single IP hop

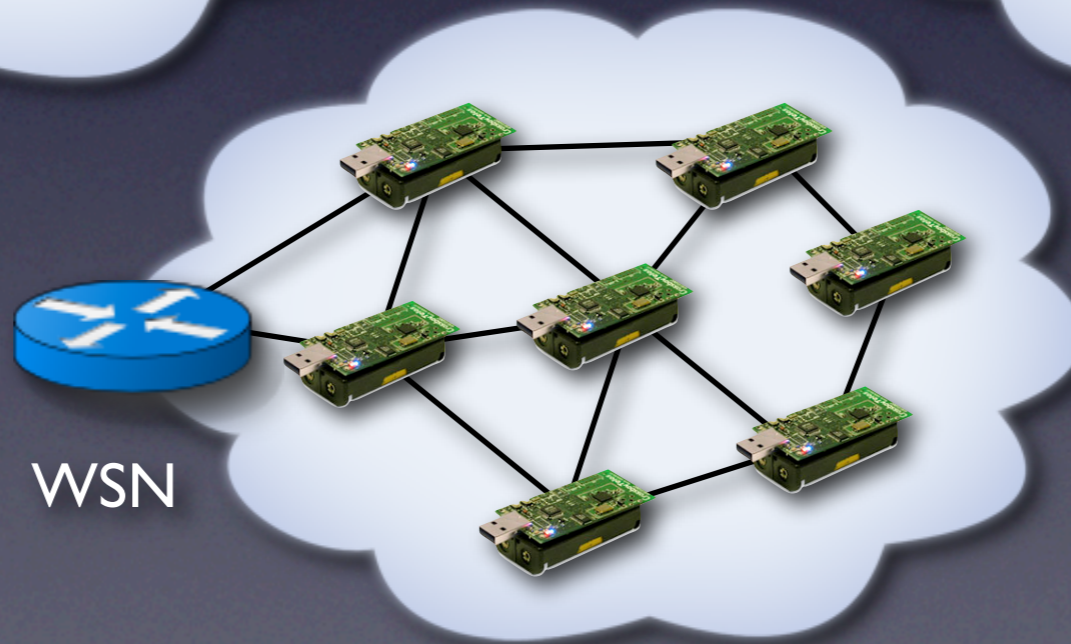
Switched Ethernet



802.11



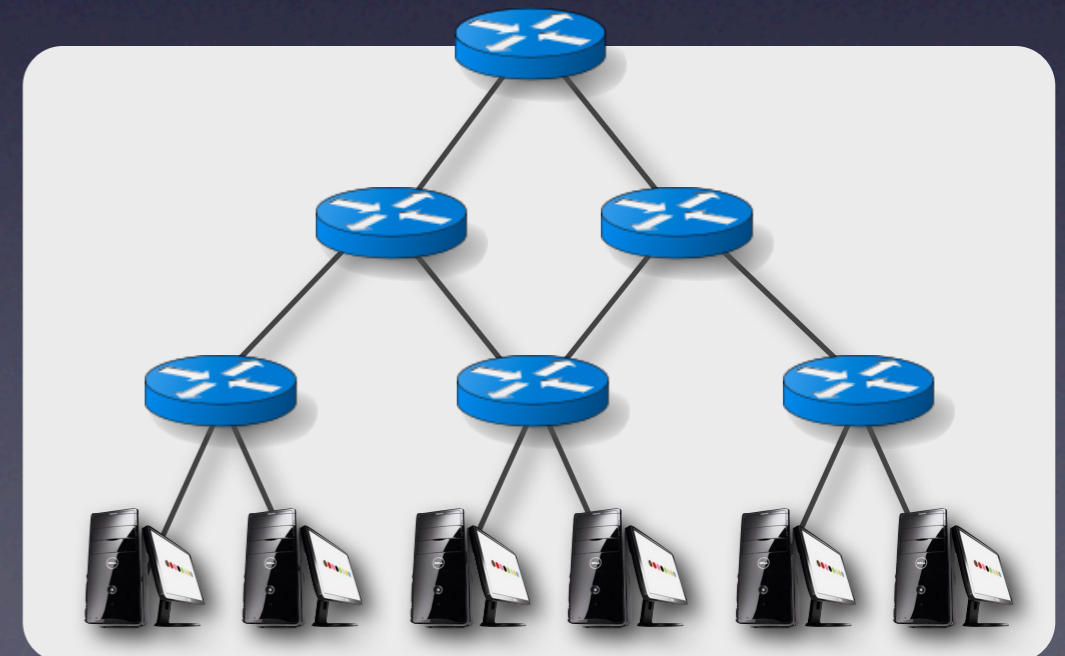
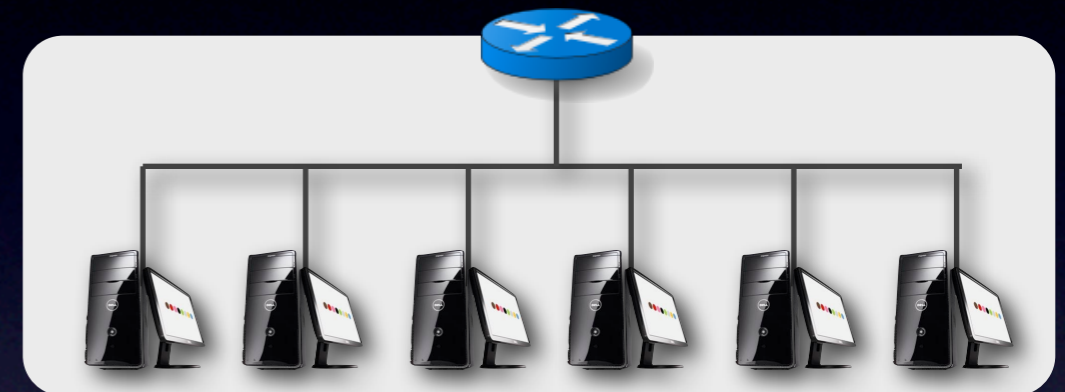
WSN



Defining the IP Link

- **Single IP Link**
 - Hide physical connectivity from IP
 - Switched Ethernet and WiFi
 - “Routing/Forwarding” at Layer 2 and Layer 3

- **Multiple IP Links**
 - IP-level visibility into physical connectivity
 - “Routing/Forwarding” only at Layer 3
 - MPLS over ATM

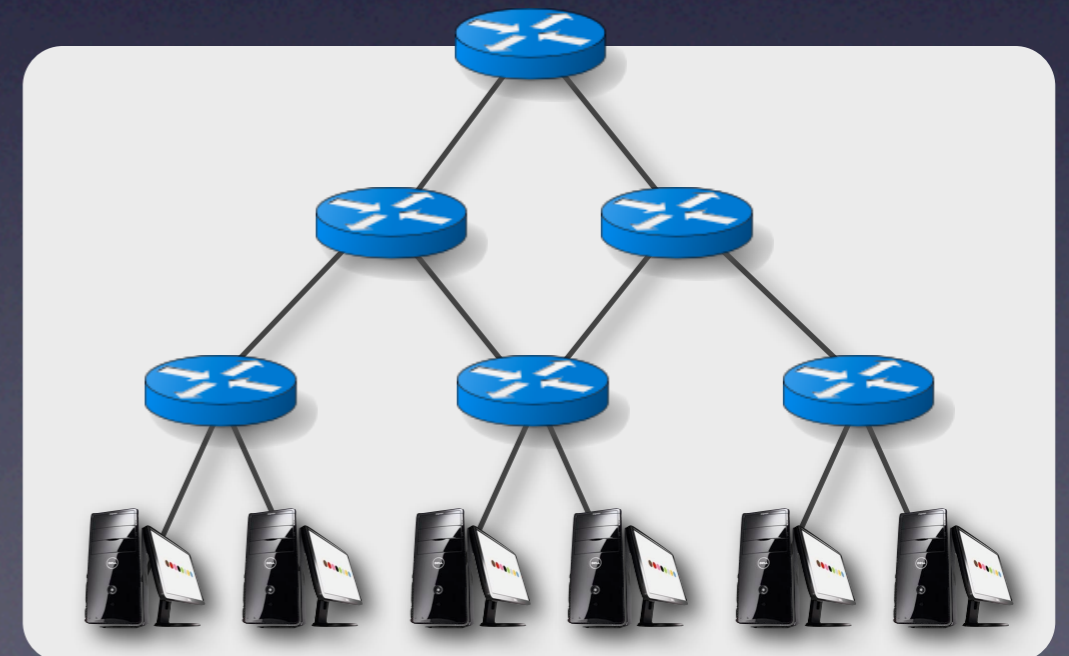


Defining the IP Link

- IP Link \Leftrightarrow PAN (mesh-under)
 - Every node is a 15.4 switch
 - Access to link-specific mechanisms
 - Hide radio specifics from IP???



- IP Link \Leftrightarrow Radio (route-over)
 - Every node is an IP router
 - Single layer of routing/forwarding
 - IP overlays based on IP



Delivering IPv6 Datagrams

6LoWPAN Adaptation



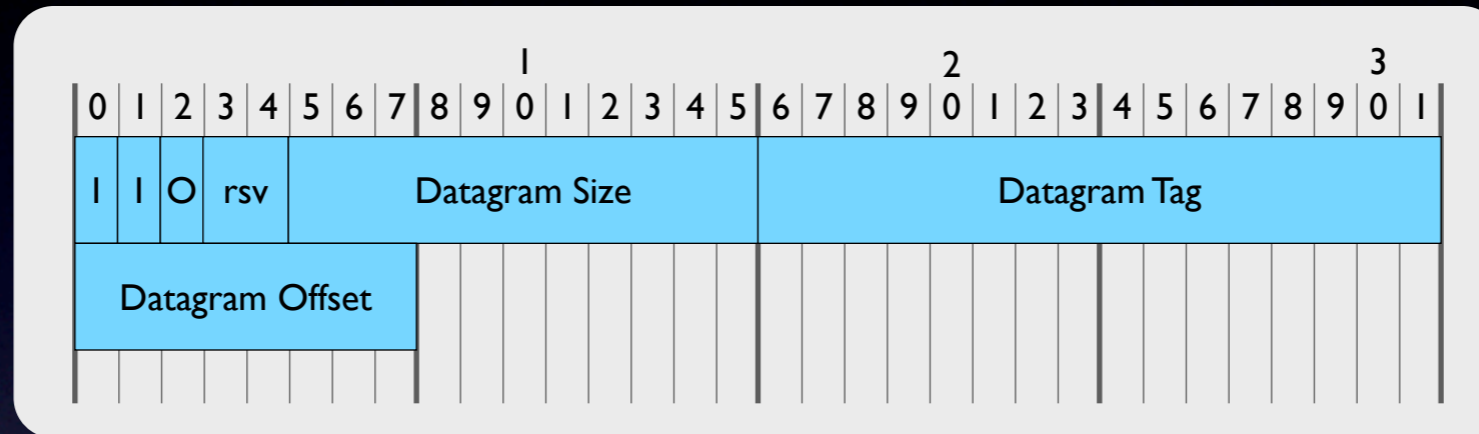
- **Fragmentation**
 - IPv6 minimum MTU requirement is 1280 bytes!
 - <http://tools.ietf.org/html/rfc4944>
- **IPv6 Header Compression**
 - Basic UDP/IPv6 header is 48 bytes!
 - <http://tools.ietf.org/html/draft-ietf-6lowpan-hc>

6LoWPAN Header Format

- “Stacked-header” format inspired by IPv6 extension headers
- Each header contains:
 - Header Type that identifies the header
 - Header-specific fields
 - Payload

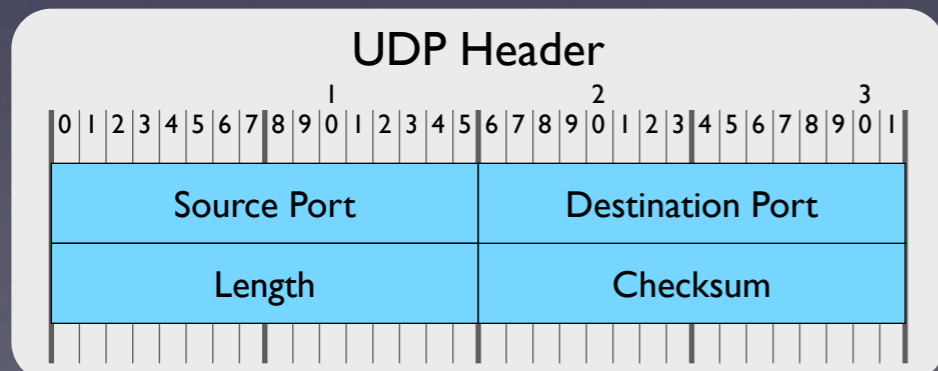
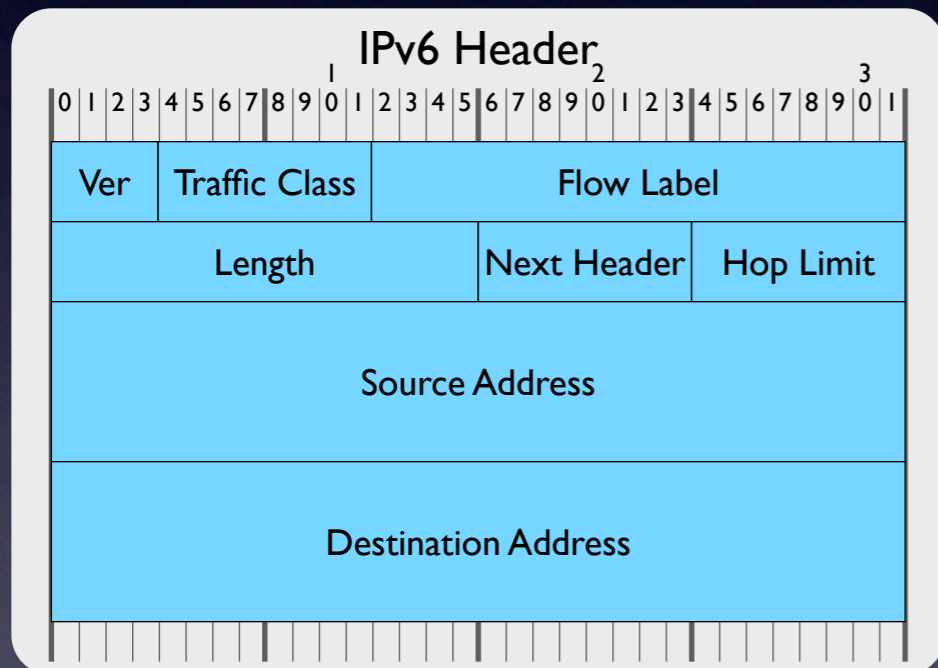
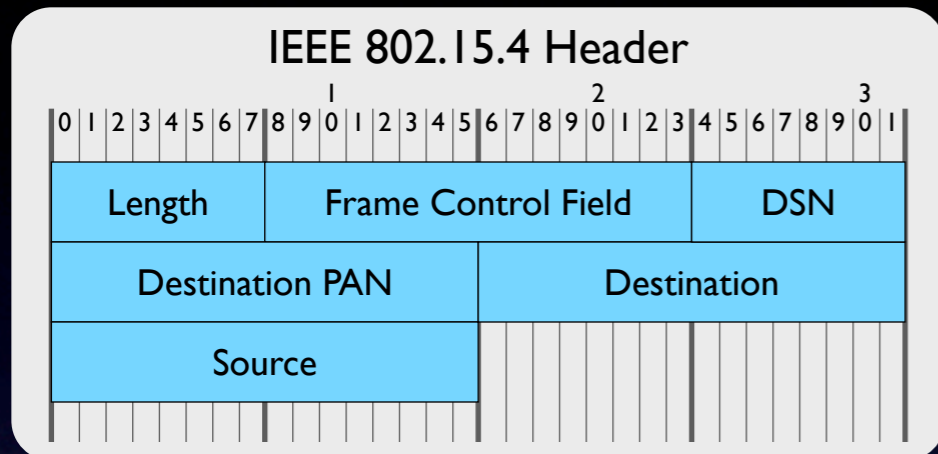


6LoWPAN Fragment Header



- First two bits identify header
- O-bit indicates if Datagram Offset is included
- 11-bit Datagram Size supports up to 2048 bytes
- Datagram Tag identifies fragments for a datagram

IPv6 Header Compression



- UDP/IPv6/15.4 Header: 58 bytes!
- Remove redundant information across layers (20.5 bytes)
 - Version (0.5): by virtue of using 6LoWPAN
 - Lengths (4): derived from 15.4 or Fragment header
 - Address suffixes (16): derived from 15.4 addresses
- Compress commonly used values (24.5 bytes)
 - Traffic Class/Flow Label (3.5): zero
 - Address prefixes (16): network prefix
 - Common multicast addresses (15): all-nodes, etc.
 - UDP ports (3): use one of 16 ports
 - Checksum (2): covered by upper layer
- Result:
 - 48-byte UDP/IPv6 header to 6 bytes in best case!

Some Examples

IEEE 802.15.4 Header - 22 bytes

| | | | | | |
|--------|-----|-----|--------|---|--|
| Length | FCF | DSN | PAN ID | Source Address (00-17-3B-FF-FE-11-22-33) | Destination Address (00-17-3B-FF-FE-44-55-66) |
|--------|-----|-----|--------|---|--|

22 bytes

Link-Local Unicast (fe80::0217:3bff:fe11:2233 → fe80::0217:3bff:fe33:4455)

| | | | | |
|----------|------|-----|-----------|--------------|
| Dispatch | IPHC | NHC | UDP Ports | UDP Checksum |
|----------|------|-----|-----------|--------------|

6 bytes

Link-Local Multicast (fe80::0217:3bff:fe11:2233 → ff02::1)

| | | | | | |
|----------|------|-----------|-----|-----------|----------|
| Dispatch | IPHC | Mcast Grp | NHC | UDP Ports | Checksum |
|----------|------|-----------|-----|-----------|----------|

7 bytes

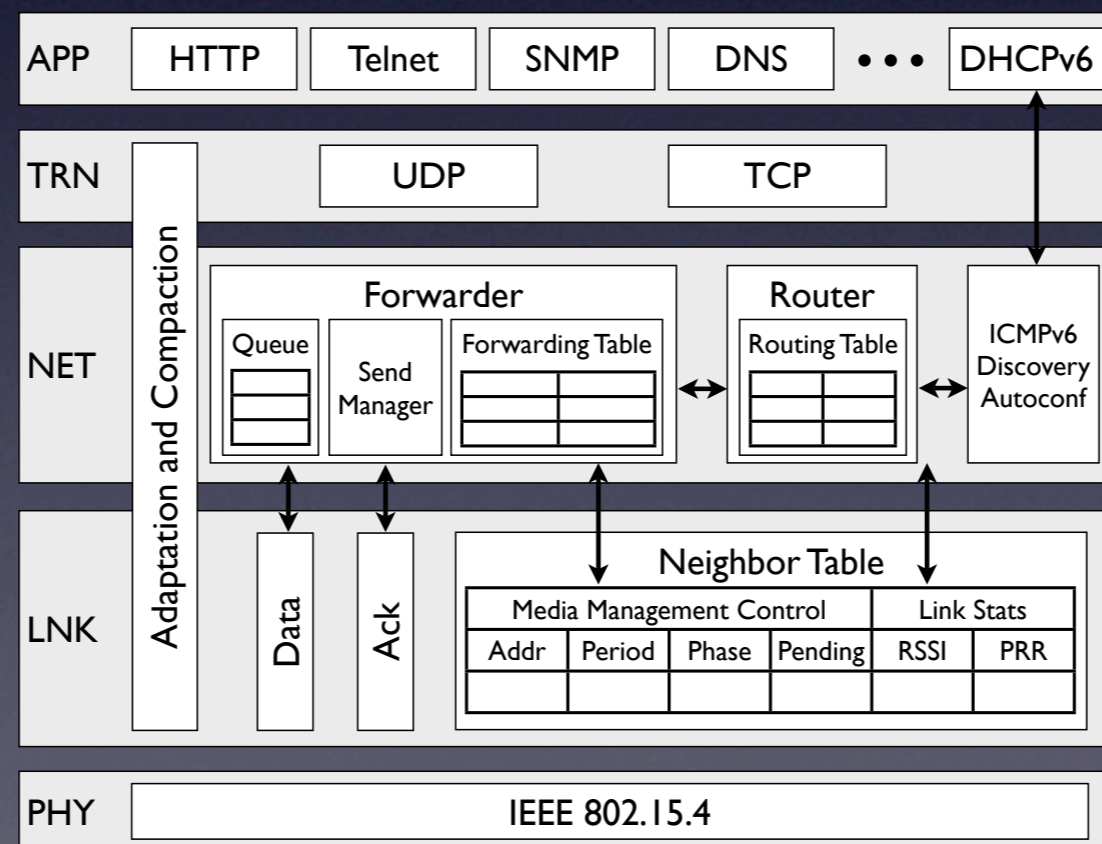
Global Unicast (2001:5a8:4:3721:0217:3bff:fe11:2233 → 2001:4860:b002::68)

| | | | | | | | |
|----------|------|-----|---------|-------------------|-----|-----------|--------------|
| Dispatch | IPHC | CID | Hop Lim | Dst IID (0068) | NHC | UDP Ports | UDP Checksum |
|----------|------|-----|---------|-------------------|-----|-----------|--------------|

10 bytes

TOSKI Overview

- Get people thinking about IPv6 sensor applications
- TinyOS-Based Network Kernel
 - 6LoWPAN adaptation layer
 - IPv6 network layer
 - UDP/TCP transport layer



TOSKI Overview

- TOSKI wrapped behind a single component:

```
configuration KernelC {  
    provides interface Boot;  
    provides interface Leds;  
  
    provides interface Udp as Udp0;  
    provides interface Tcp as Tcp0;  
}
```

- Single socket for UDP and TCP each
- Included with the evaluation release:
 - Simple Telnet server
 - Simple Http server
 - Simple MSP430 ADC I2 driver

Hands-on

- Now let's play with TOSKI.