TinyOS Technology Exchange IV

Saturday April 28, M.I.T.

ArchRock

TinyOS meets IP -- finally

David E. Culler

THE Question

If Wireless Sensor Networks represent a future of "billions of information devices embedded in the physical world,"

why don't they run ***THE*** standard internetworking protocol?

The Answer

They should

- Substantially advances the state-of-the-art in both domains.
- Implementing IP requires tackling the general case, not just a specific operational slice
  - Interoperability with all other potential IP network links
  - Potential to name and route to any IP-enabled device within security domain
  - Robust operation despite external factors
    - Coexistence, interference, errant devices, ...
- While meeting the critical embedded wireless requirements
  - High reliability and adaptability
  - Long lifetime on limited energy
  - Manageability of many devices
  - Within highly constrained resources

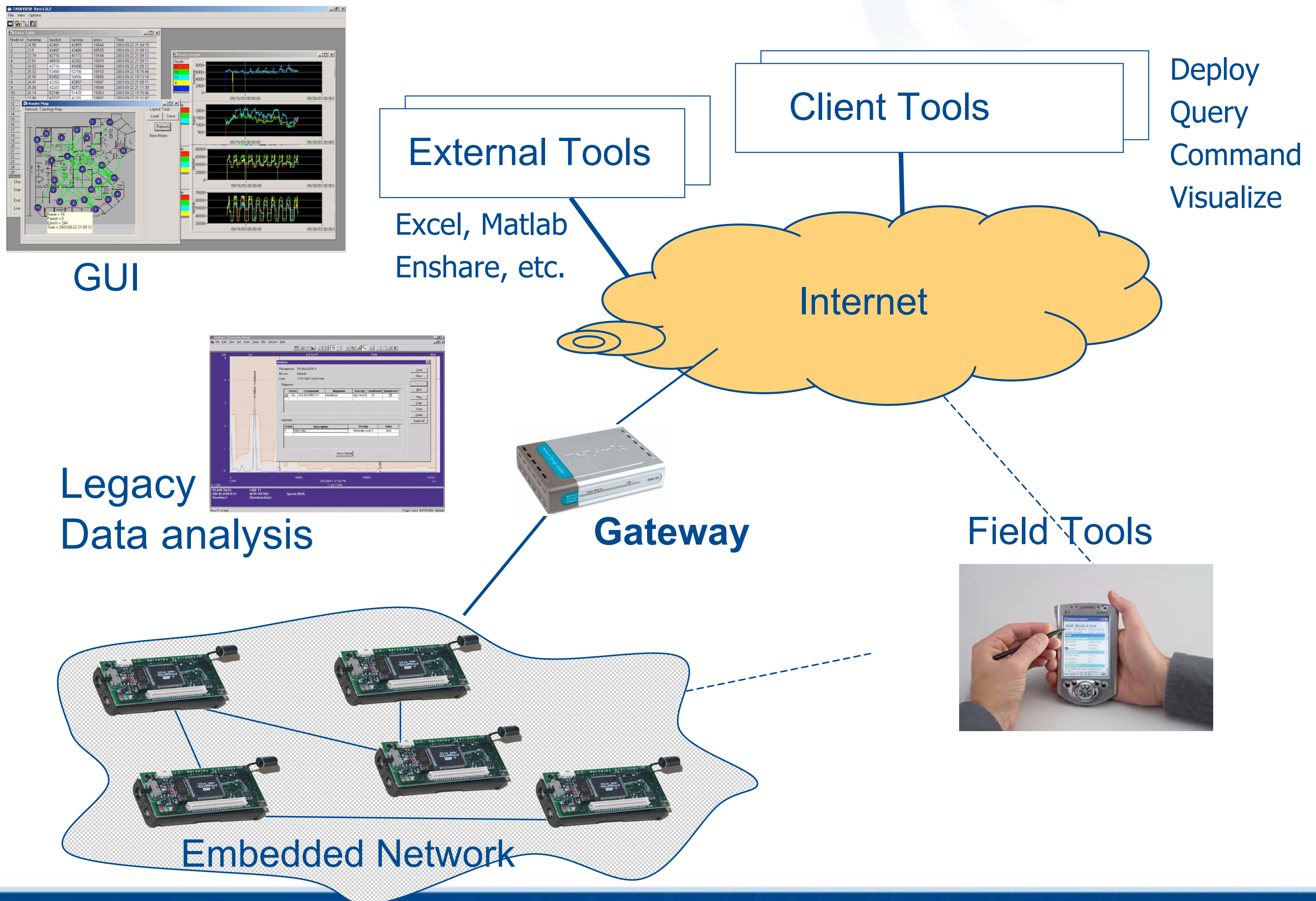
Many Advantages of IP

- **Extensive interoperability**
  - Other wireless embedded 802.15.4 network devices
  - Devices on any other IP network link (WiFi, Ethernet, GPRS, Serial lines, …)
- **Established security**
  - Authentication, access control, and firewall mechanisms
  - Network design and policy determines access, not the technology
- **Established naming, addressing, translation, lookup, discovery**
- **Established proxy architectures for higher-level services**
  - NAT, load balancing, caching, mobility
- **Established application level data model and services**
  - HTTP/HTML/XML/SOAP/REST, Application profiles
- **Established network management tools**
  - Ping, Traceroute, SNMP, … OpenView, NetManager, Ganglia, …
- **Transport protocols**
  - End-to-end reliability in addition to link reliability
- **Most “industrial” (wired and wireless) standards support an IP option**

Challenges for IP over 802.15.4

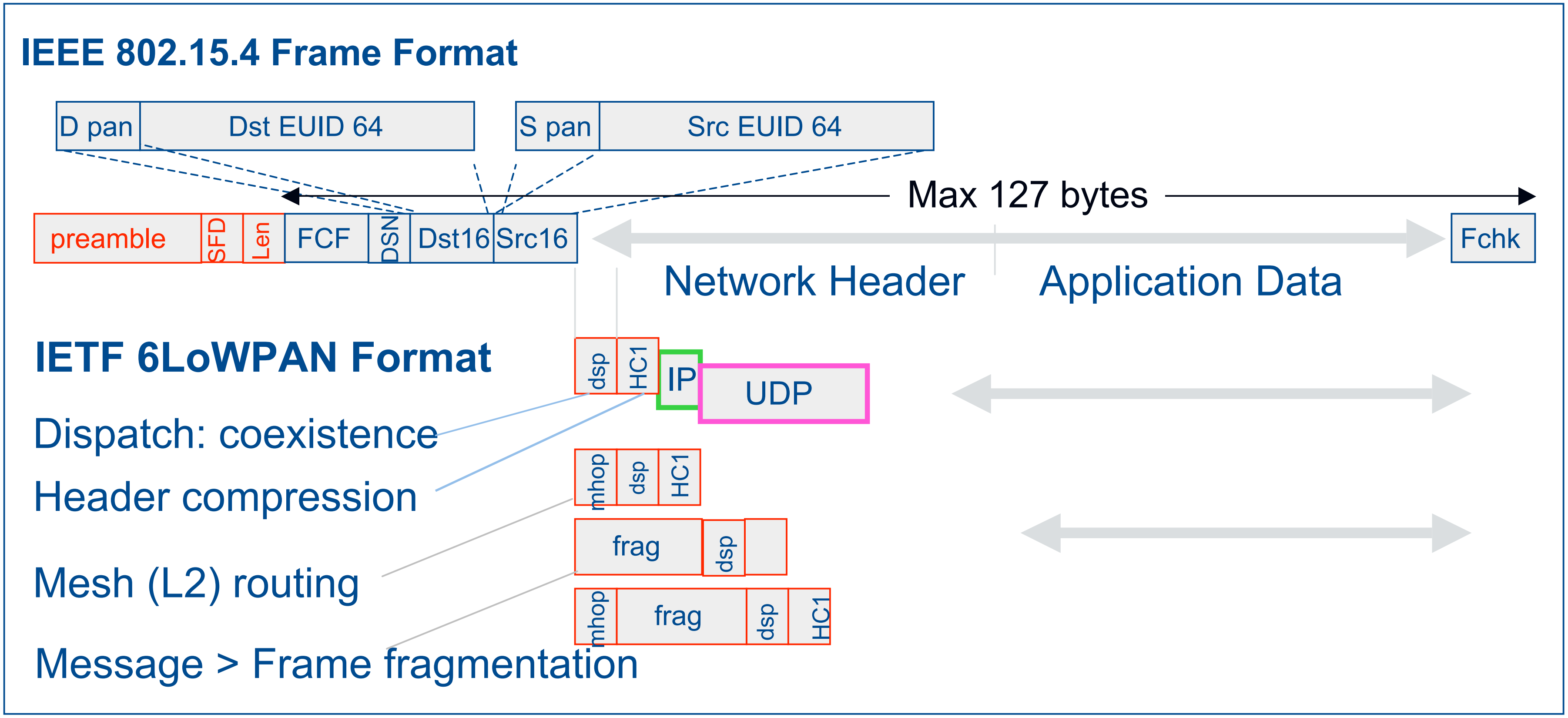
- Header
  - Standard IPv6 header is 40 bytes [RFC 2460]
  - Entire 802.15.4 MTU is 127 bytes [IEEE]
  - Often data payload is small
- Fragmentation
  - Interoperability means that applications need not know the constraints of physical links that might carry their packets
  - IP packets may be large, compared to 802.15.4 max frame size
  - IPv6 requires all links support 1280 byte packets [RFC 2460]
- Allow link-layer mesh routing under IP topology
  - 802.15.4 subnets may utilize multiple radio hops per IP hop
  - Similar to LAN switching within IP routing domain in Ethernet
- Allow IP routing over a mesh of 802.15.4 nodes
  - Options and capabilities already well-defines
  - Various protocols to establish routing tables

WSNs we've all been building



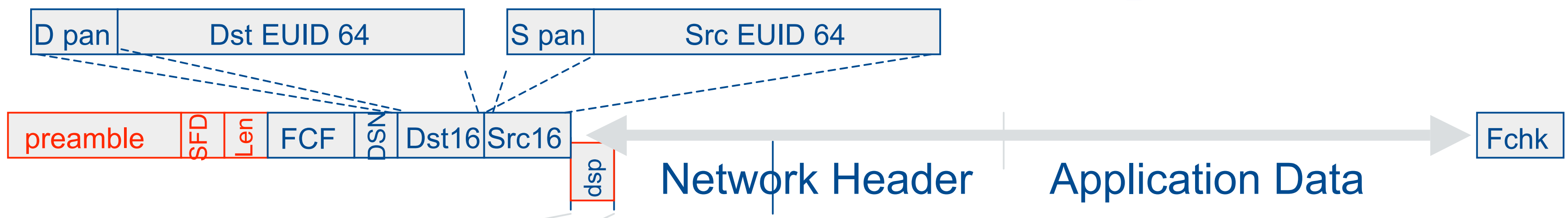
6LoWPAN Format Design

- Orthogonal stackable header format
- Almost no overhead for the ability to interoperate and scale.
- Pay for only what you use

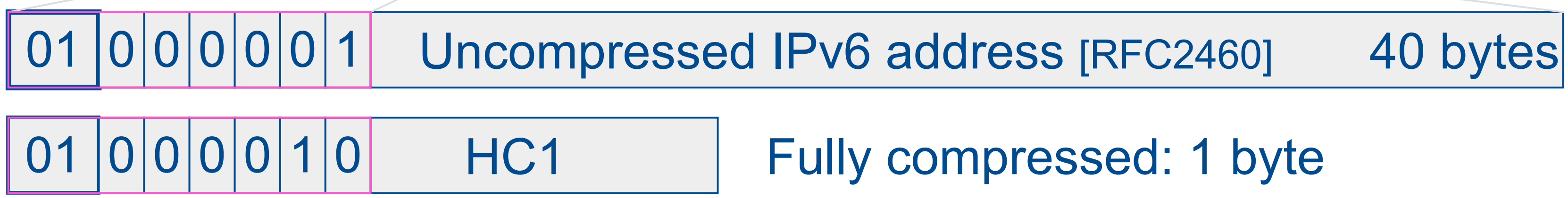


6LoWPAN – IPv6 Header

IEEE 802.15.4 Frame Format



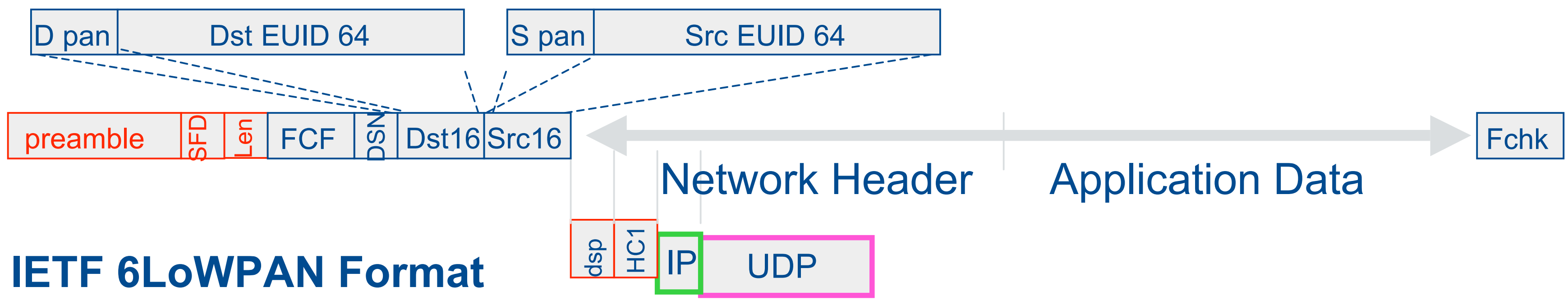
IETF 6LoWPAN Format



Source address	: derived from link address
Destination address	: derived from link address
Traffic Class & Flow Label	: zero
Next header	: UDP, TCP, or ICMP

6LoWPAN – Compressed / Compressed UDP

IEEE 802.15.4 Frame Format



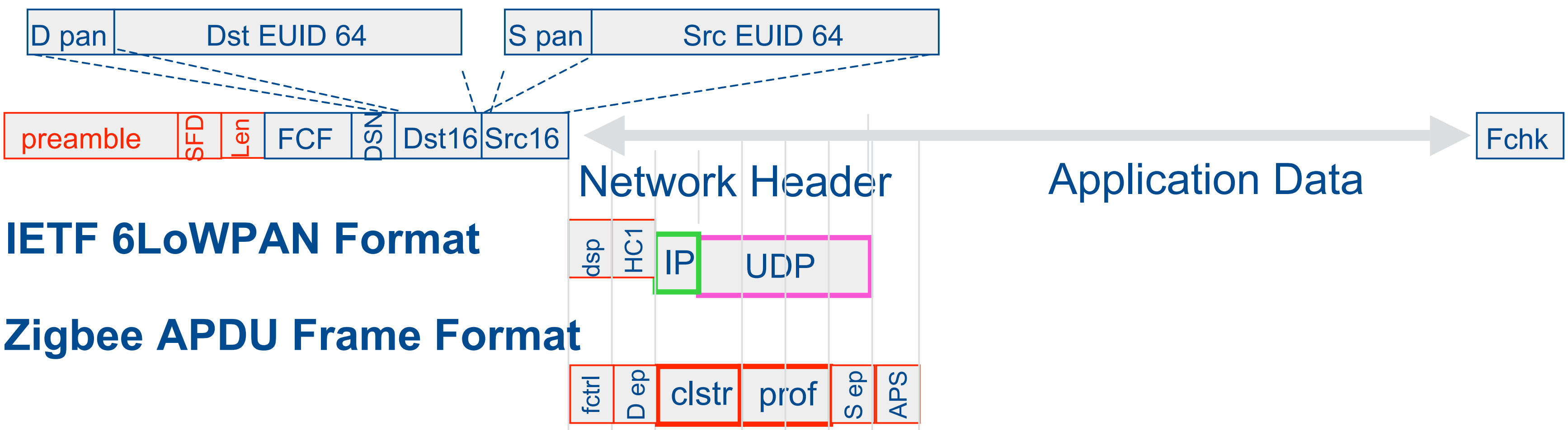
IETF 6LoWPAN Format

Dispatch: Compressed IPv6

HC1: Source & Dest Local, next hdr=UDP
IP: Hop limit
UDP: 4-byte header (compressed)
source port = P + 4 bits, p = 61616 (0xF0B0)
destination port = P + 4 bits

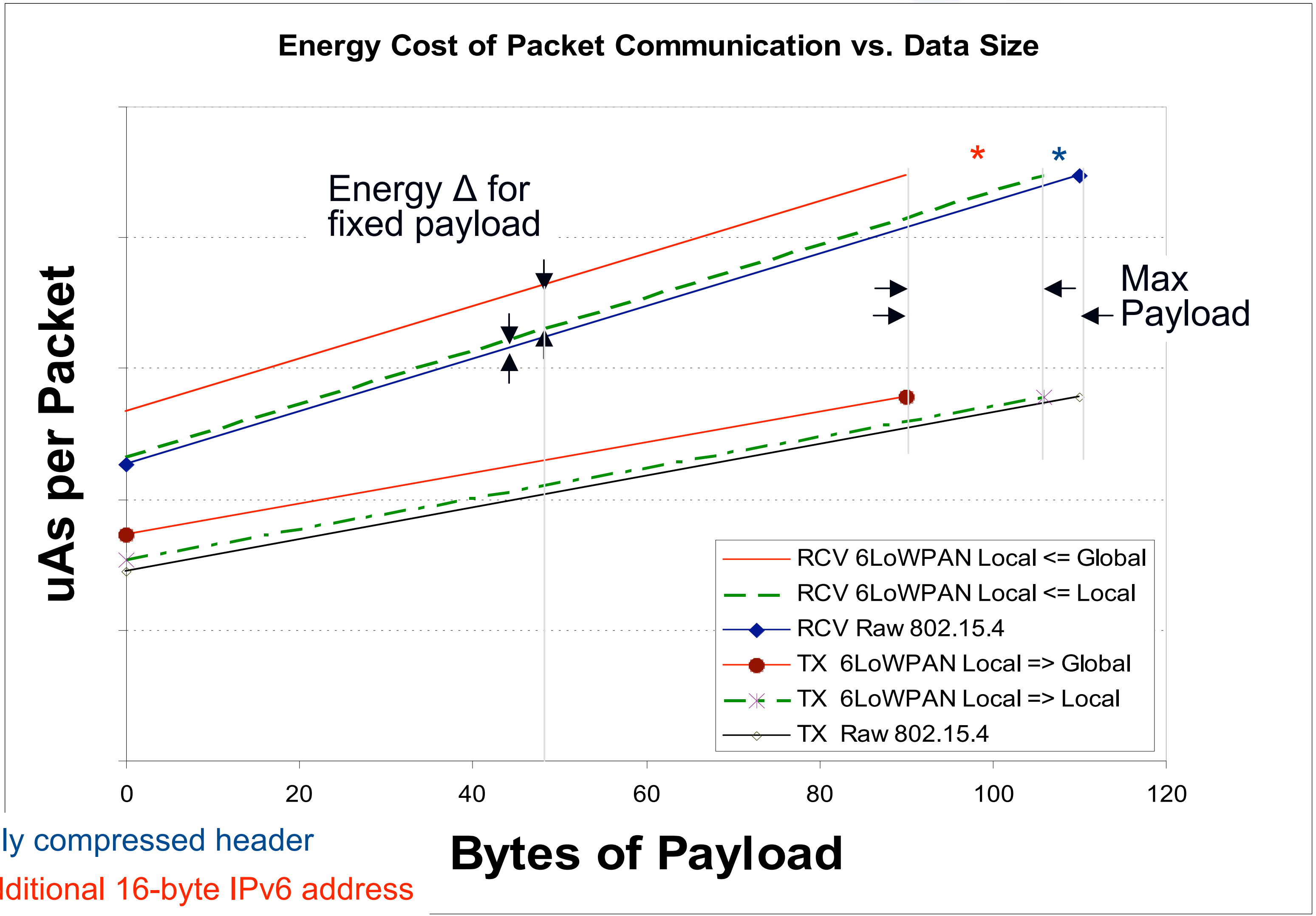
6LoWPAN / Zigbee Comparison

IEEE 802.15.4 Frame Format



fctrl: Frame Control bit fields
D ep: Destination Endpoint (like UDP port)
clstr: cluster identifier
prof: profile identifier
S ep: Source Endpoint
APS: APS counter (sequence to prevent duplicates)
*** Typical configuration. Larger and smaller alternative forms exist.

Low Impact of 6LoWPAN on Lifetime – Comparison to *Raw* 802.15.4 Frame



* fully compressed header

* additional 16-byte IPv6 address

What it means for TinyOS.net?

- 6LoWPAN is just the beginning
  – How bits go on the air
- Rest of the IETF standards mean that you can get real solutions built today.
- Huge array of arbitrary decisions become easy
  – Do it like the RFC!
- Much easier to integrate, compare, build on, …
  – bMAC, sMAC, tMAX, xMAC, zMAC should use same format.
  – Mesh-under, route-over well-defined.
  – Route formation distinct from forwarding
- Whole set of issues to resolve
  – Equivalent of sockets API to invent
  – RIP, OSPF, IGP, EGP, …. => [your routing protocol here]
  – Geographic naming => IP address
  – Dissemination / Agrregation ⇔ Multicast Groups

...and beyond TinyOS

- mailto: rsn@ietf.org