UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

6LoWPAN

Adaptação do IPv6 para a Internet das Coisas

Disciplina:
Redes Sem Fio

Professora
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CPGEI/UTFPR

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Curitiba, 21 de agosto de 2015

Introdução

IPv6 + 802.15.4 = Internet das Coisas

- IoT, justificar o uso do IEEE 802.15.4

- Como fica a topologia e a Pilha de Protocolos

- Necessidade de Adaptação

- Resumir endereços, fragmentar datagramas e comprimir cabeçalhos.

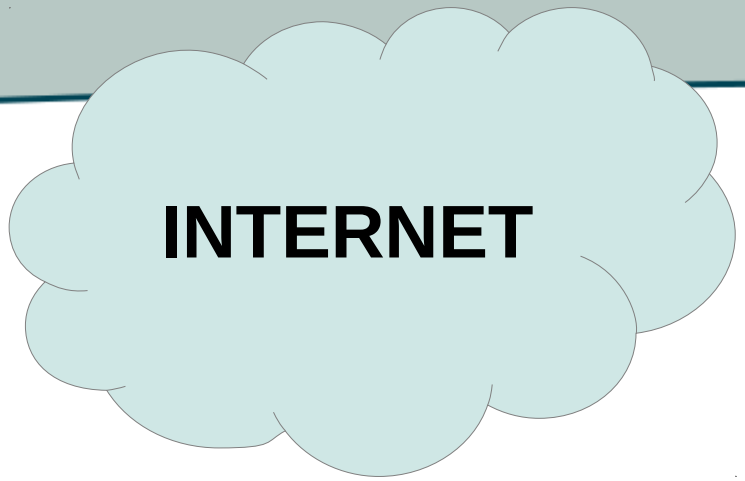
- Adaptar protocolos IPv6, NDP, ICMPv6, UDP

- Novos protocolos: RPL, CoAP

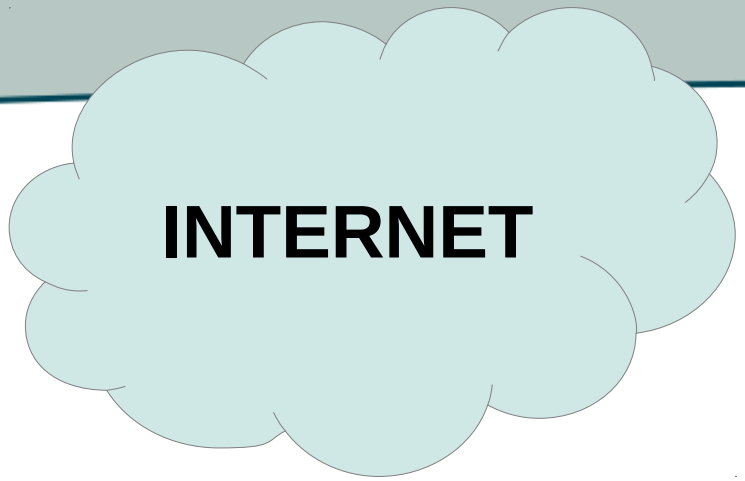
- Necessidade de Segurança e Criptografia

- Prospecção, Exemplos de Mercado e Pesquisa

6LoWPAN e a IoT



6LoWPAN e a IoT



Aplicações WEB

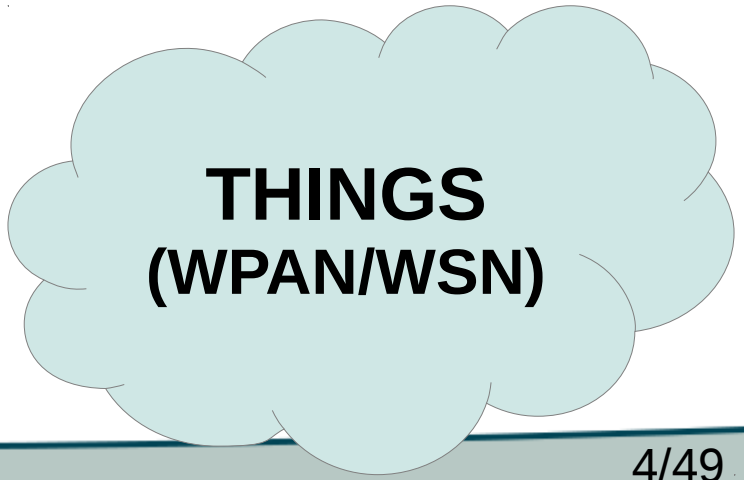
Comunicação TCP/IP (IPv6)

Automação residencial

Monitoração industrial

Ambientes hospitalares

...



INTERNET

Aplicações WEB

Comunicação TCP/IP (IPv6)

1 – Consumo de Energia
2 – Confiabilidade
3 – Compatibilidade

Automação residencial

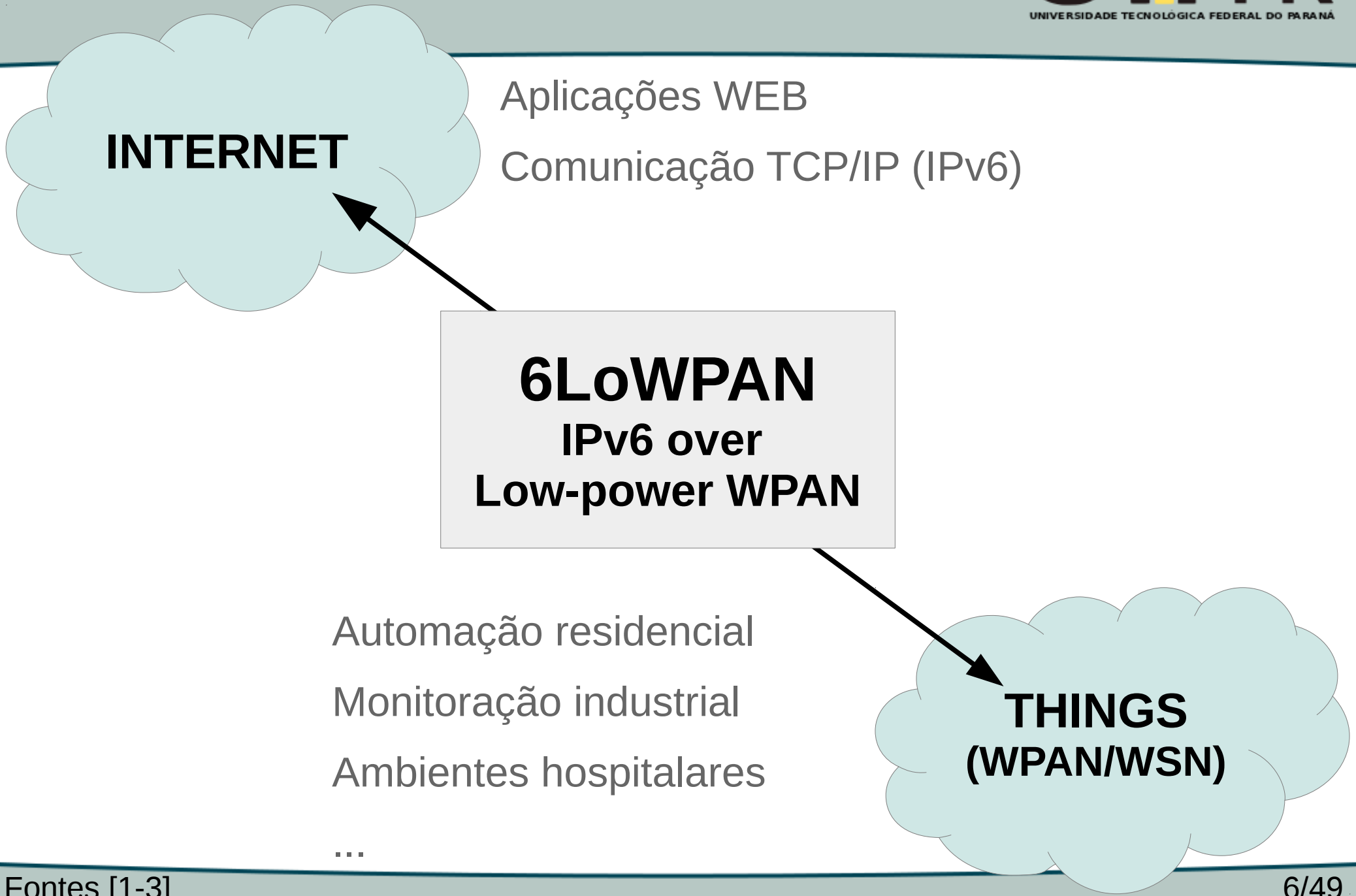
Monitoração industrial

Ambientes hospitalares

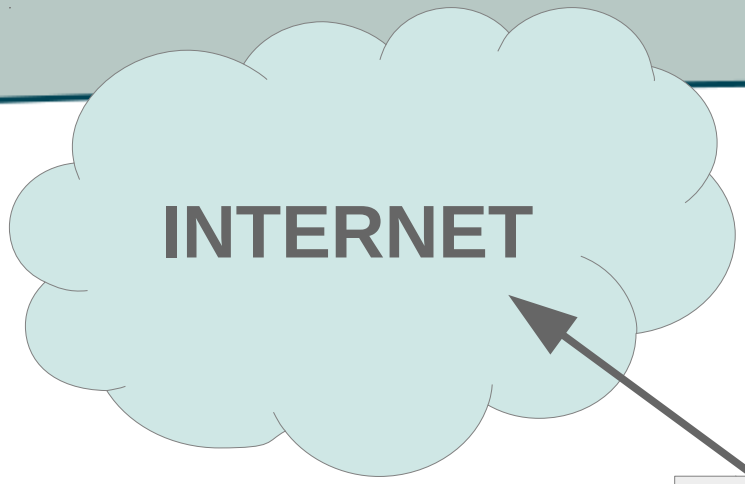
...

THINGS
(WPAN/WSN)

6LoWPAN e a IoT



6LoWPAN e a IoT



Aplicações WEB

Comunicação TCP/IP (IPv6)

6LoWPAN
IPv6 over
Low-power WPAN

Projeção:

Em 2020 serão

50 bilhões de

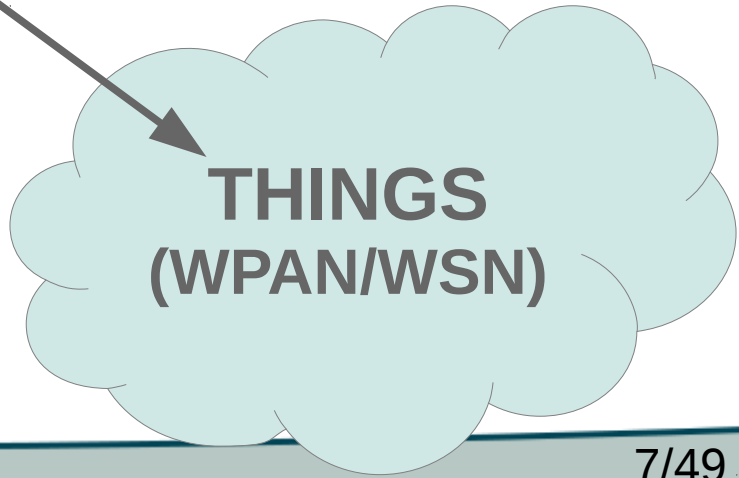
dispositivos na IoT.

Automação residencial

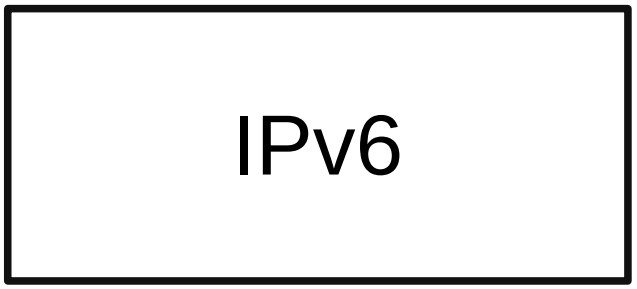
Monitoração industrial

Ambientes hospitalares

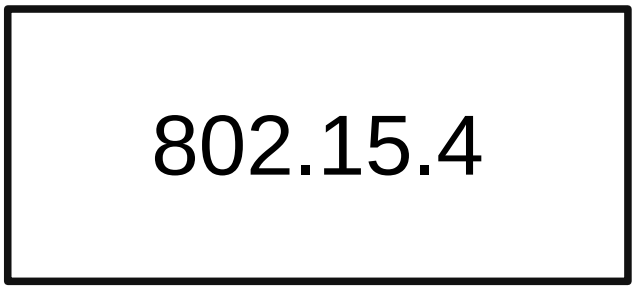
...



IETF 6LoWPAN e o IEEE 802.15.4

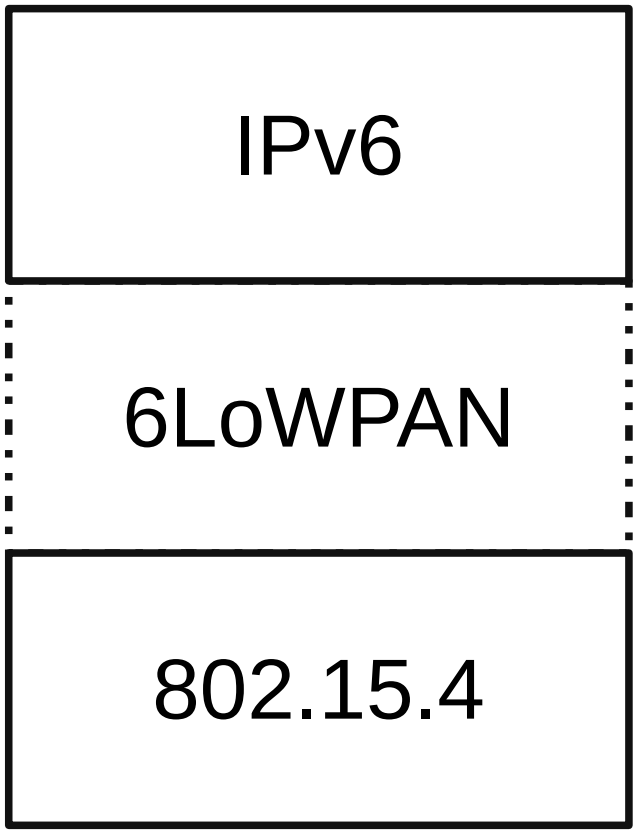


IETF – Arquitetura TCP/IP



IEEE – MAC/PHY

IETF 6LoWPAN e o IEEE 802.15.4

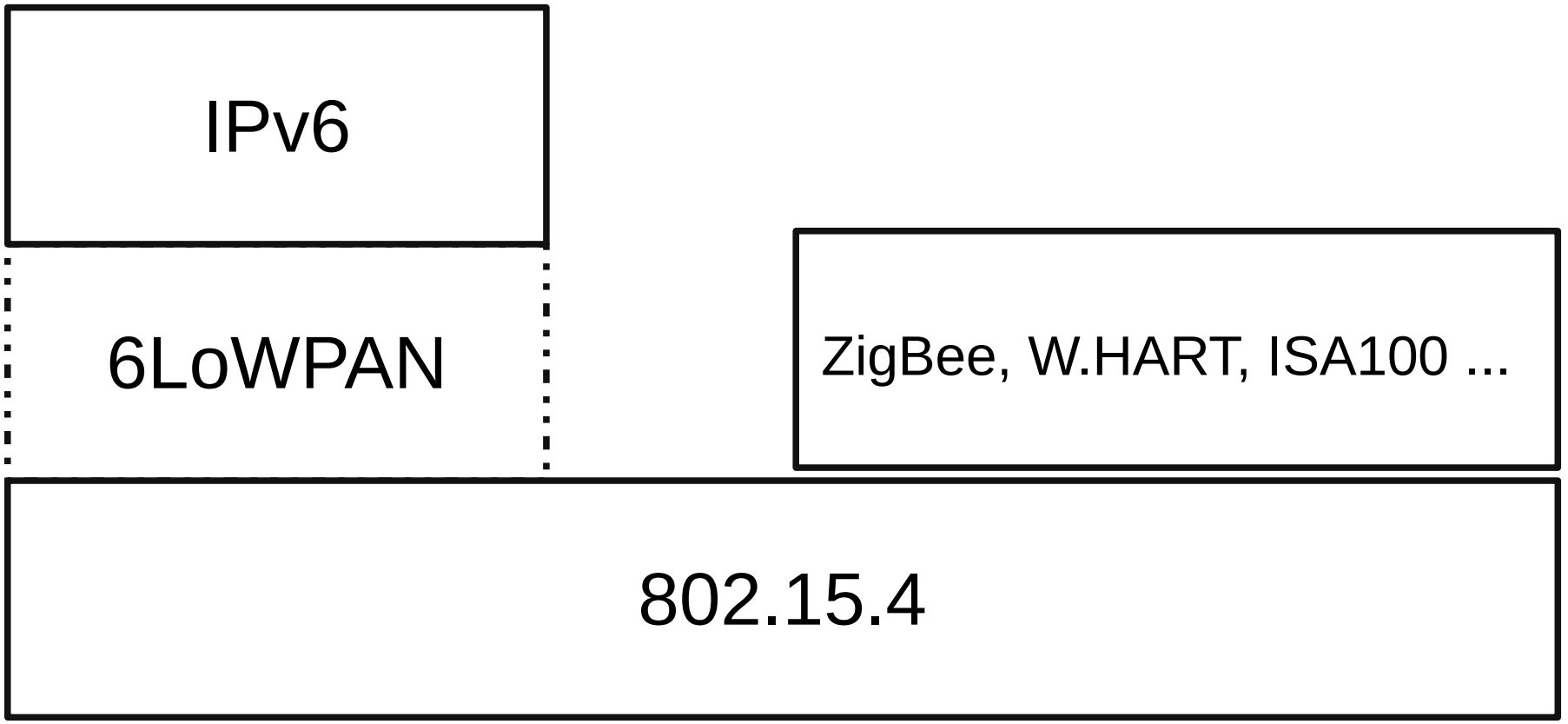


IETF – Arquitetura TCP/IP

IETF – Camada de Adaptação

IEEE – MAC/PHY

IETF 6LoWPAN e o IEEE 802.15.4



ISM – 2400-2483.5 MHz – max 250 Kbps

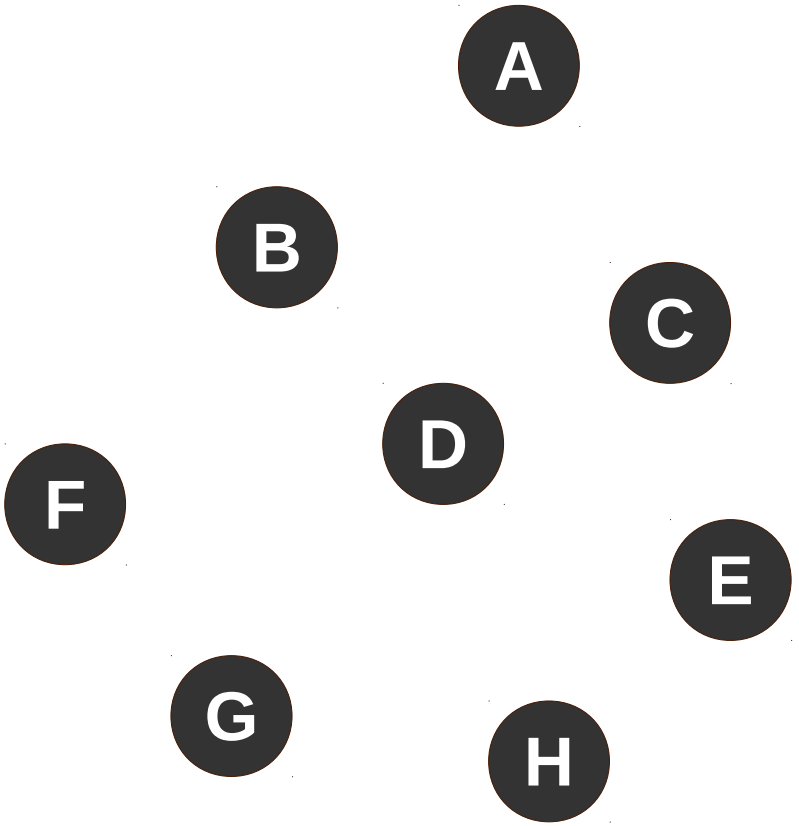
Gravogl et Al. [6] comparam o consumo de Energia:

	Sleep	**Tx**	**Rx**
IEEE 802.15.4			
Bluetooth			
WiFi			

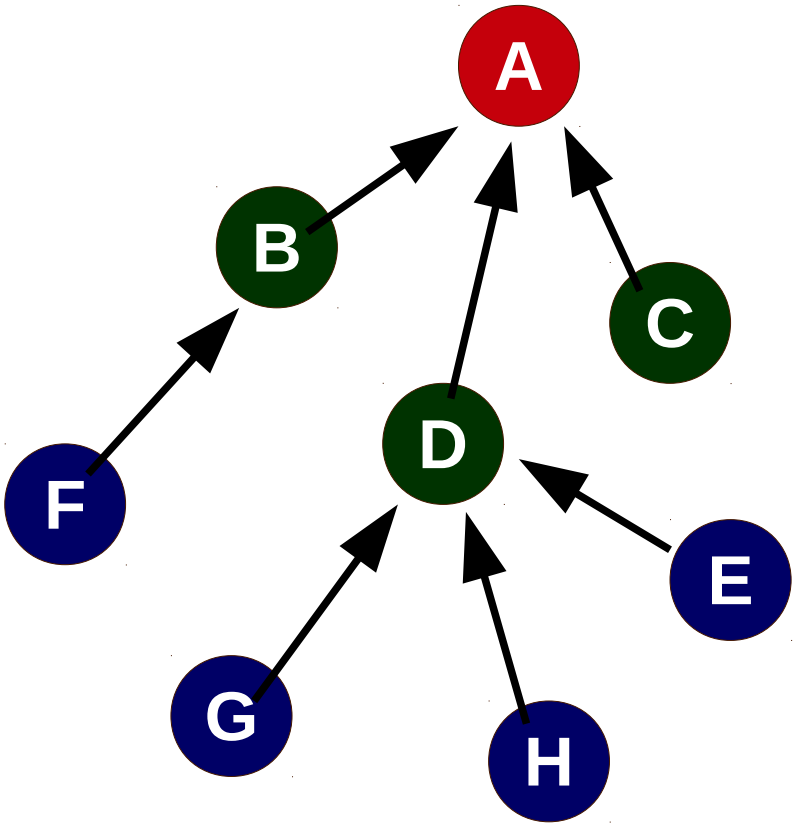
Gravogl et Al. [6] comparam o consumo de Energia:

	Sleep	**Tx**	**Rx**
IEEE 802.15.4	0,06 µW	36,9 mW	34,8 mW
Bluetooth	330,00 µW	215,0 mW	215,0 mW
WiFi	6600,00 µW	835,0 mW	1550,0 mW

Topologias



Topologia IEEE 802.15.4



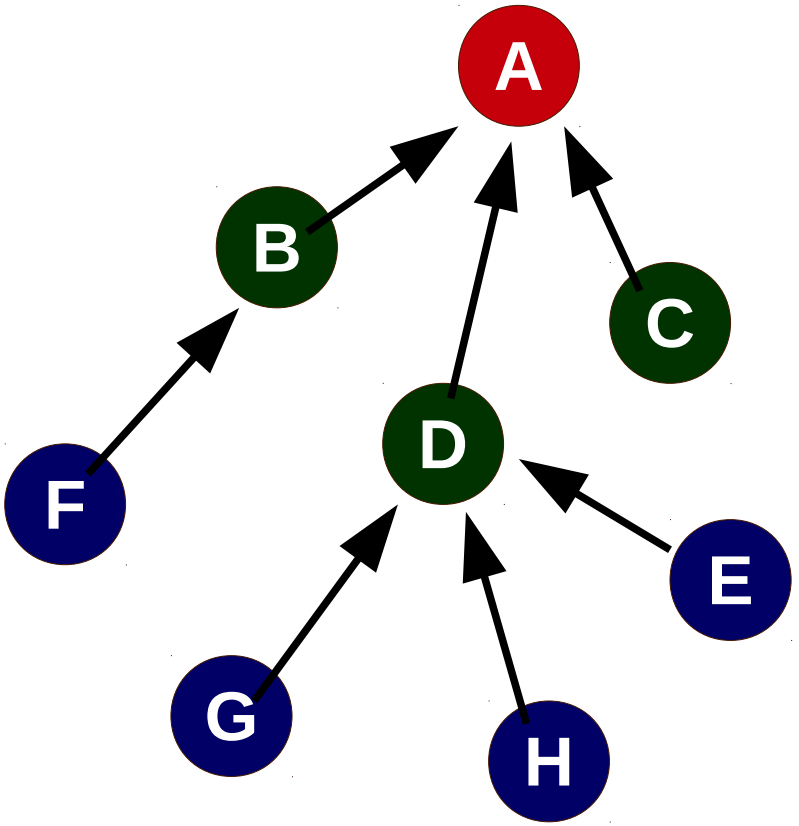
Star/Peer-to-peer

PAN Coordinator

FFD (Full Function)

RFD (Reduced Func.)

Topologia 6LoWPAN



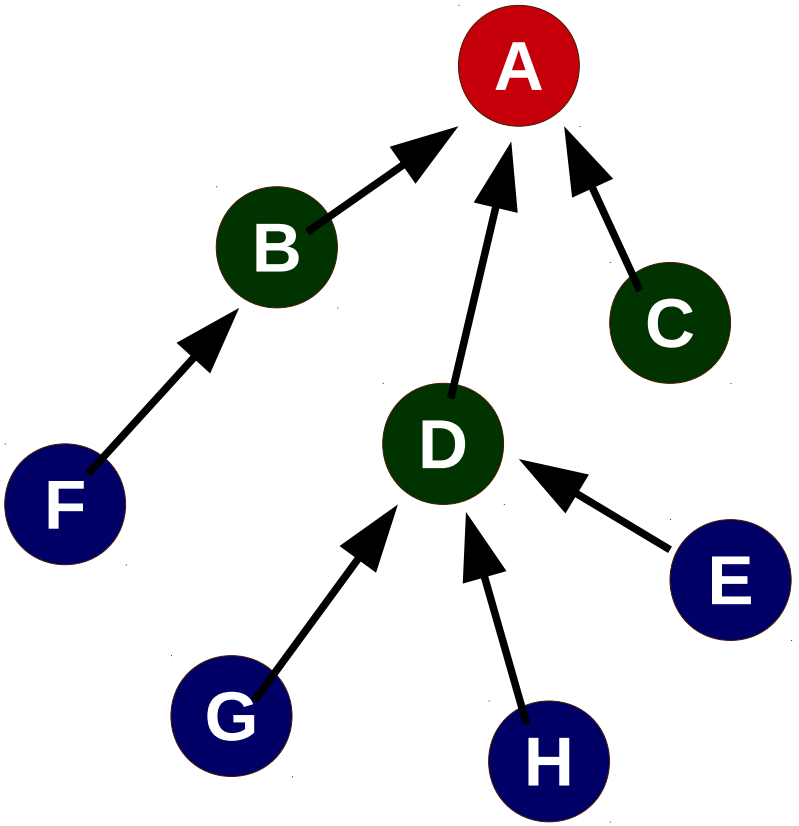
Star/Mesh

LBR (Border Router)

LC (Local Controller)

N (Nodes)

Topologia 6LoWPAN/IEEE 802.15.4



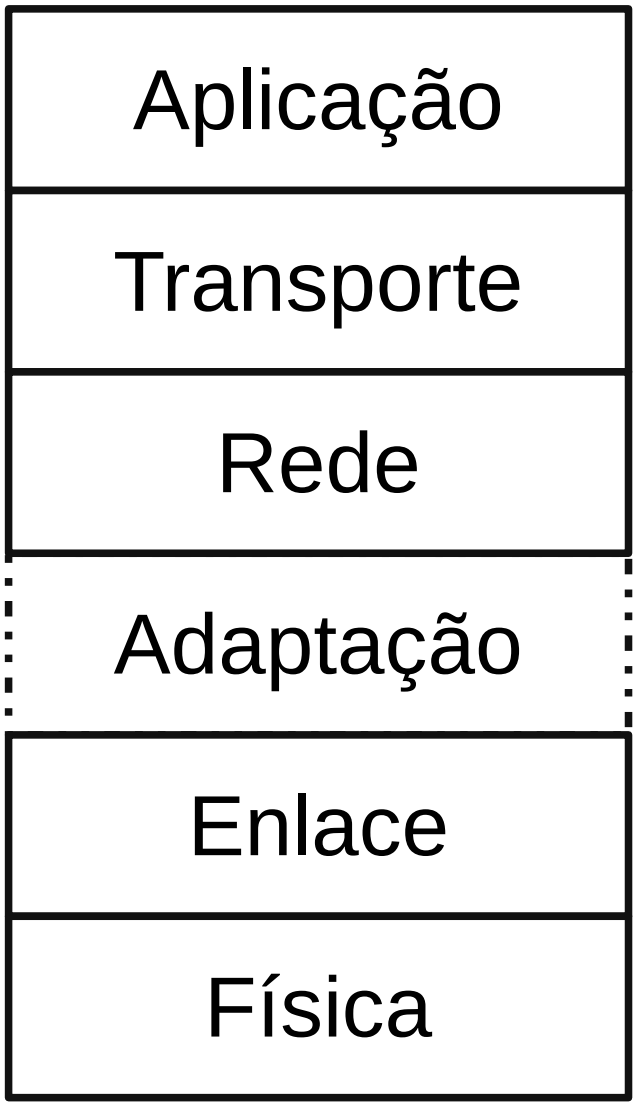
Star/Mesh

LBR (Border Router)
[PAN Coord. e FFD]

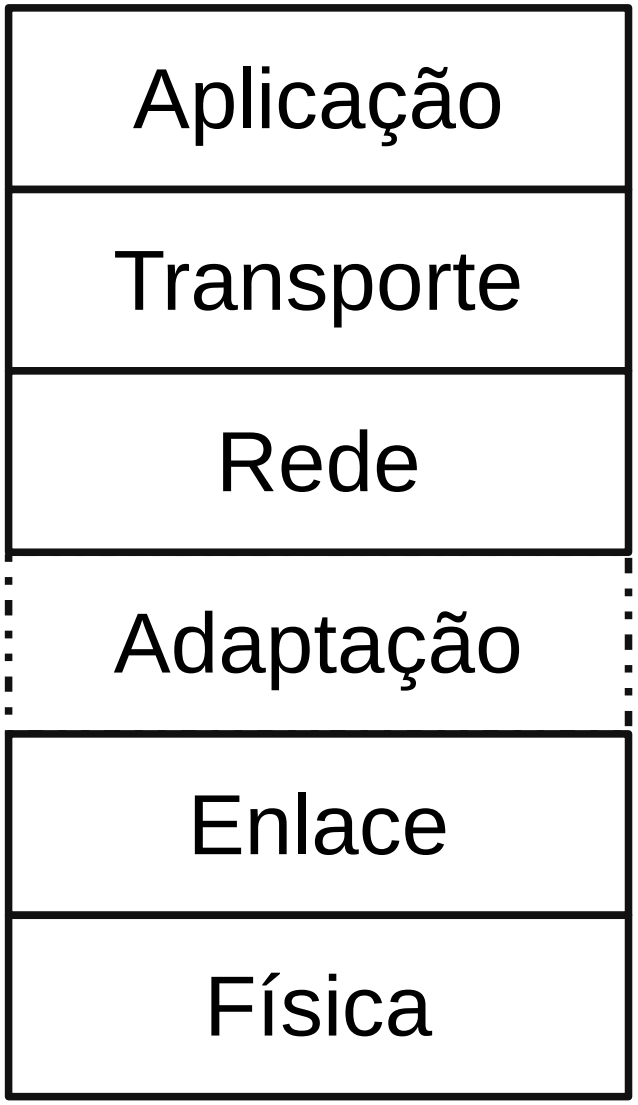
LC (Local Controller)
[FFD]

N (Nodes)
[FFD/RFD]

Pilha de Protocolos



Pilha de Protocolos



CoAP

UDP

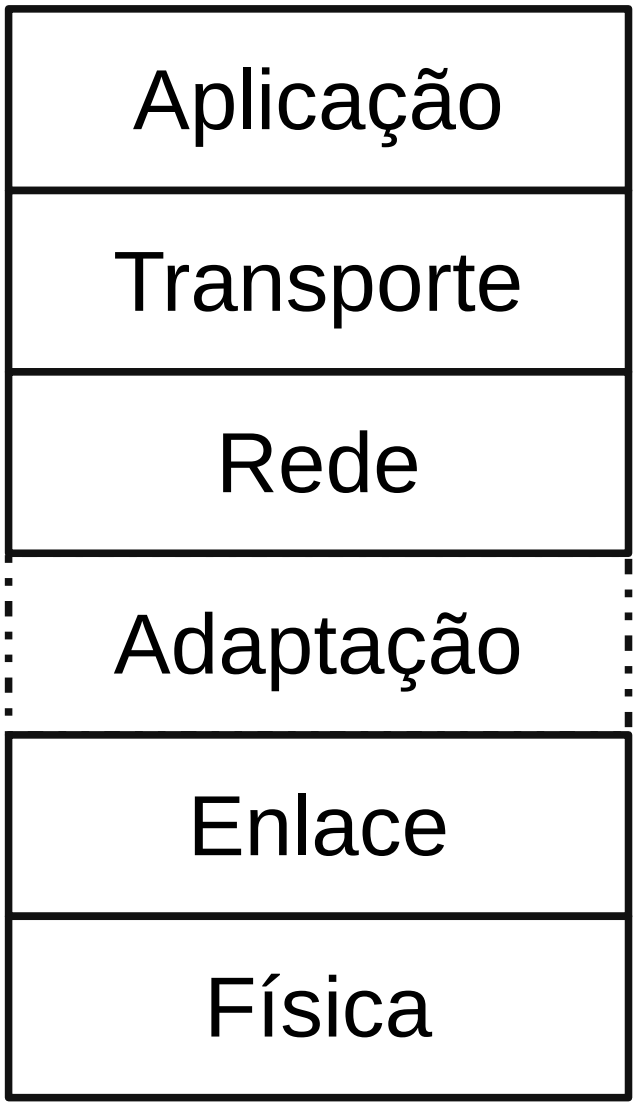
IPv6 (ICMPv6 / 6Lo-DP / RPL)

6LoWPAN

IEEE 802.15.4 MAC

IEEE 802.15.4 PHY

Pilha de Protocolos



CoAP

UDP

IPv6 (ICMPv6 / 6Lo-DP / RPL)

Resumo / Fragmentação / Compressão

IEEE 802.15.4 MAC

IEEE 802.15.4 PHY

Resumo de Endereços

		Addr.	Total
IPv6	Normal = 128 bits	16 bytes	32 bytes
MAC	Extended Address 64 bits	8 bytes	16 bytes

Resumo de Endereços

		Addr.	Total
IPv6	Normal = 128 bits	16 bytes	32 bytes
	Half = 64 bits	8 bytes	16 bytes
	Max = 16 bits	4 bytes	8 bytes
	Address elided	0 bytes	0 bytes
MAC	Extended Address 64 bits	8 bytes	16 bytes
	Short Address 16 bits	2 bytes	4 bytes

Resumo de Endereços

		Addr.	Total
IPv6	Normal = 128 bits	16 bytes	32 bytes
	Half = 64 bits	8 bytes	16 bytes
	Max = 16 bits	4 bytes	8 bytes
	Address elided	0 bytes	0 bytes
MAC	Extended Address 64 bits	8 bytes	16 bytes
	Short Address 16 bits	2 bytes	4 bytes

IEEE 802.15.4 – Tamanho total do frame = 127 bytes.

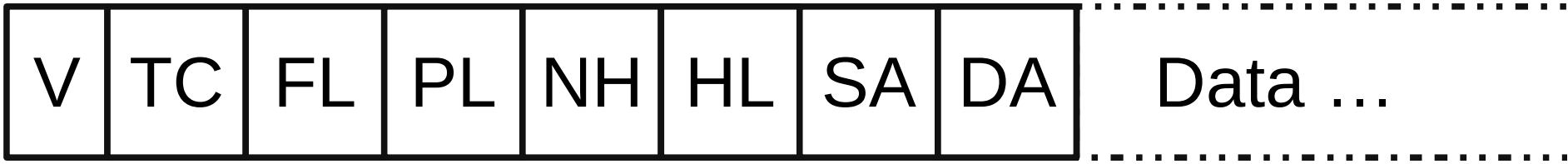
Economia máxima = 44 bytes.

Fragmentação de Datagramas

FRAME IEEE 802.15.4

Fragmentação de Datagramas

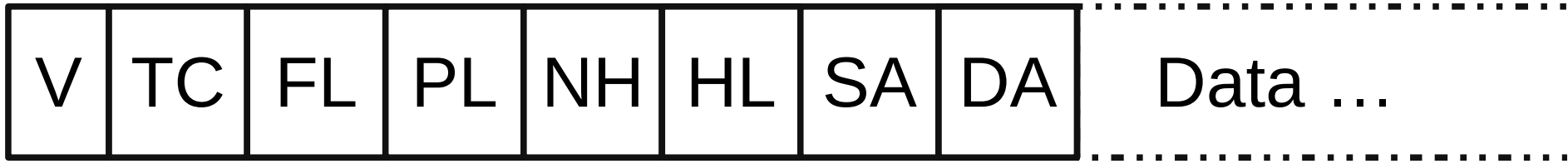
DATAGRAMA IPv6



FRAME IEEE 802.15.4

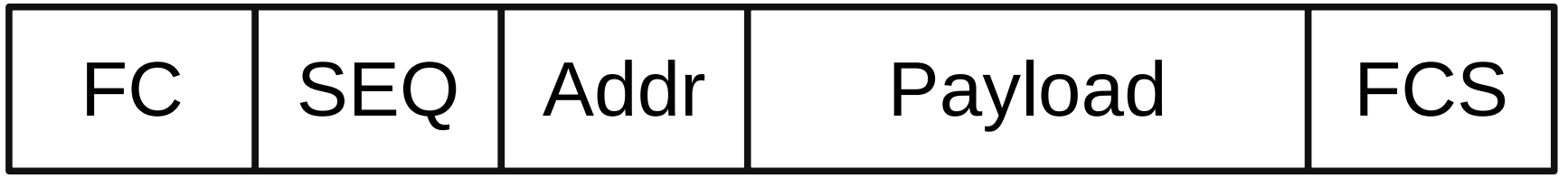
Fragmentação de Datagramas

DATAGRAMA IPv6



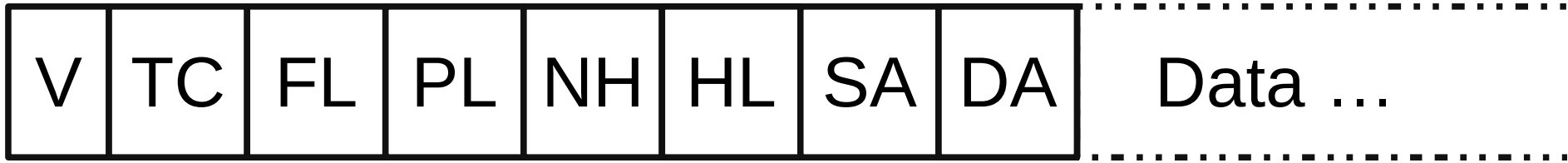
MTU mínima 1280 Bytes

FRAME IEEE 802.15.4



Fragmentação de Datagramas

DATAGRAMA IPv6

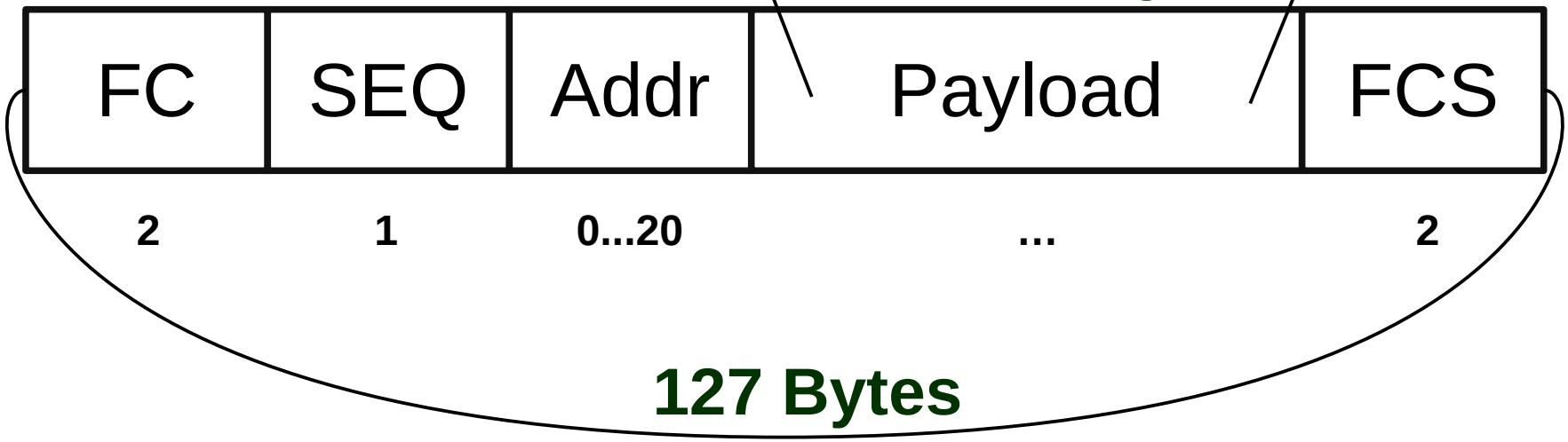


MTU mínima 1280 Bytes

≠

MTU 102 Bytes

FRAME IEEE 802.15.4

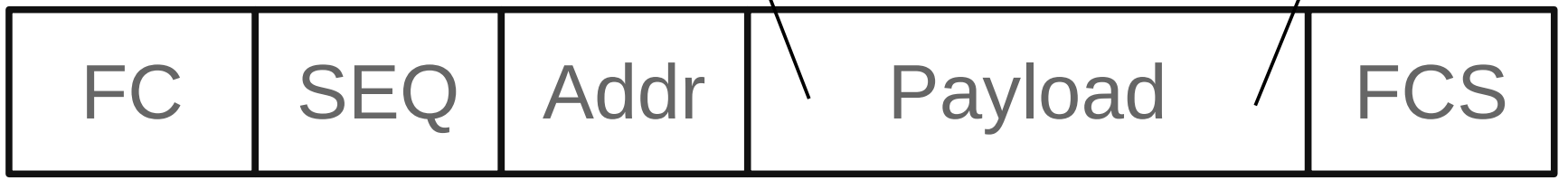


Fragmentação de Datagramas

DATAGRAMA IPv6

FRAME IEEE 802.15.4

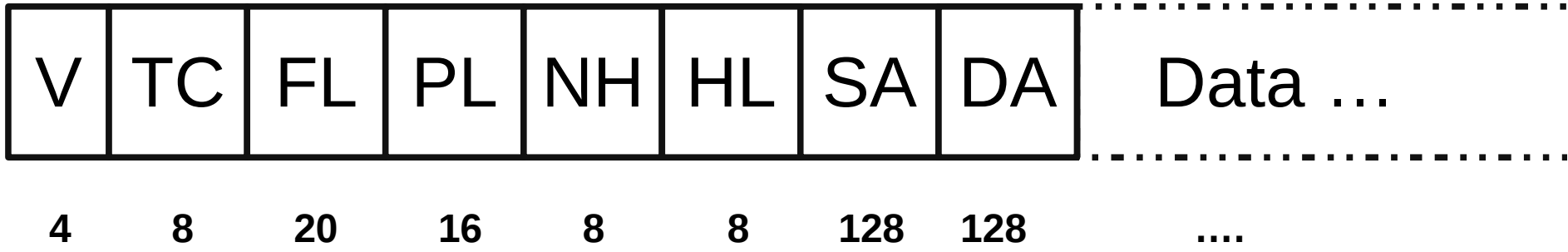
LoWPAN_IPHC



Campos adicionais: size, tag, offset

Compressão do Cabeçalho

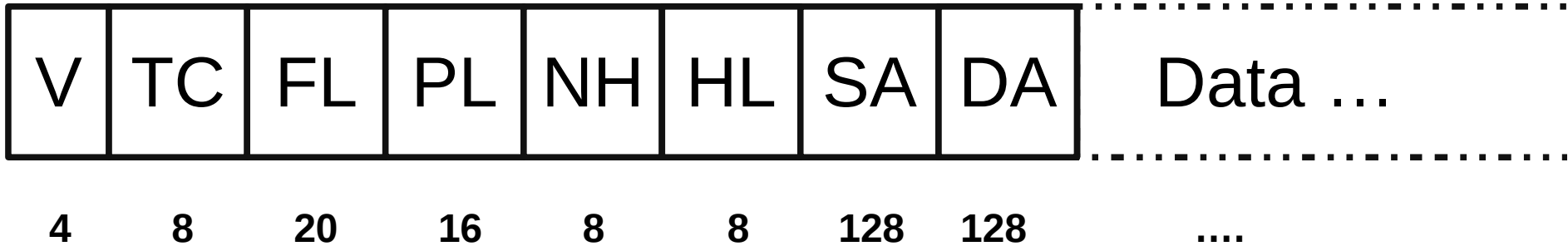
Cabeçalho do Datagrama IPv6



320 bits = 40 bytes

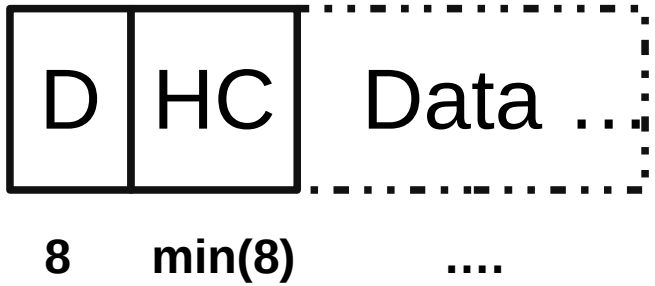
Compressão do Cabeçalho

Cabeçalho do Datagrama IPv6



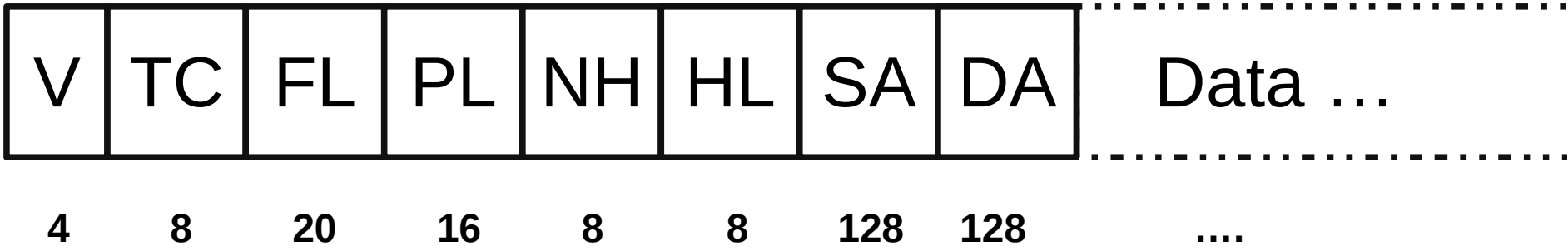
320 bits = 40 bytes

Cabeçalho do Datagrama LoWPAN_IPHC



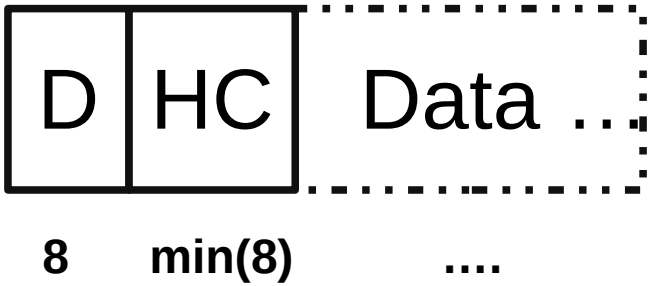
Compressão do Cabeçalho

Cabeçalho do Datagrama IPv6



320 bits = 40 bytes

Cabeçalho do Datagrama LoWPAN_IPHC

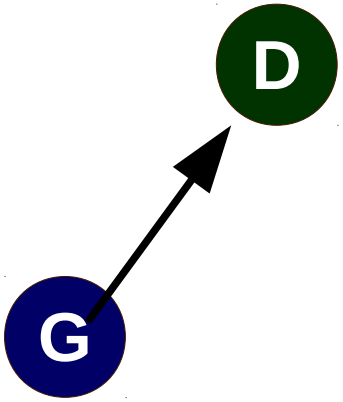


Tamanho mínimo do cabeçalho:

Não roteável 16 bits = 2 bytes

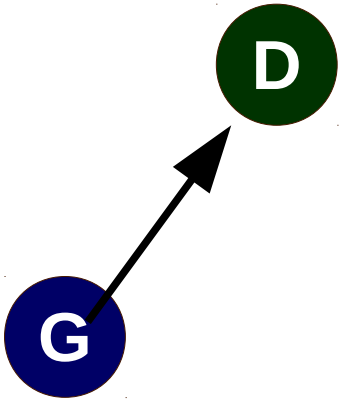
Roteável 56 bits = 7 bytes

6LoWPAN-ND



Network Discovery Protocol

6LoWPAN-ND



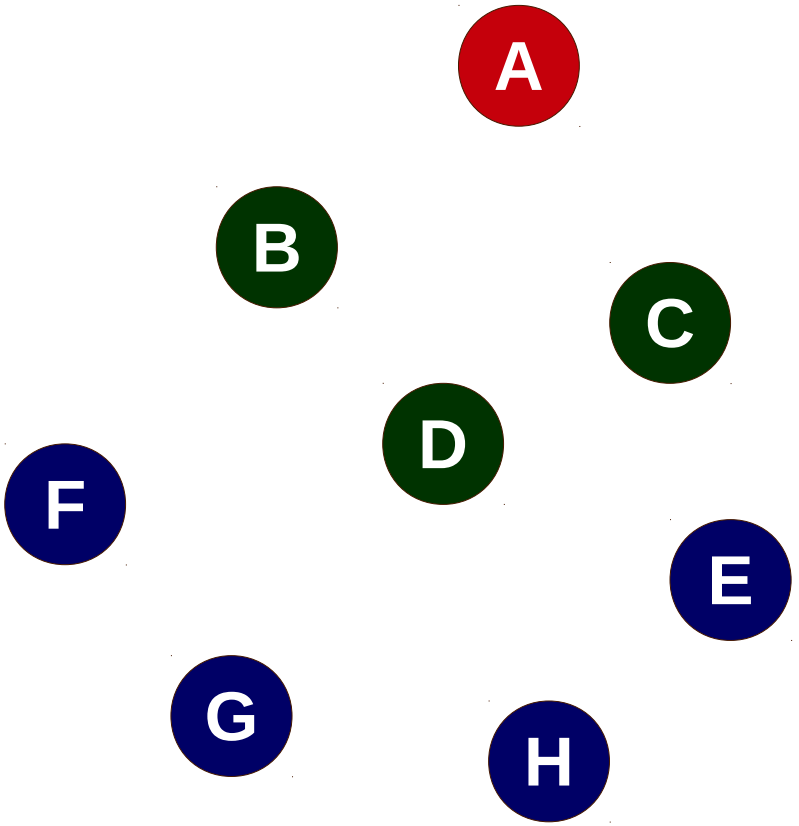
Network Discovery Protocol

- Neighbor, Gateway
- Duplicated Address

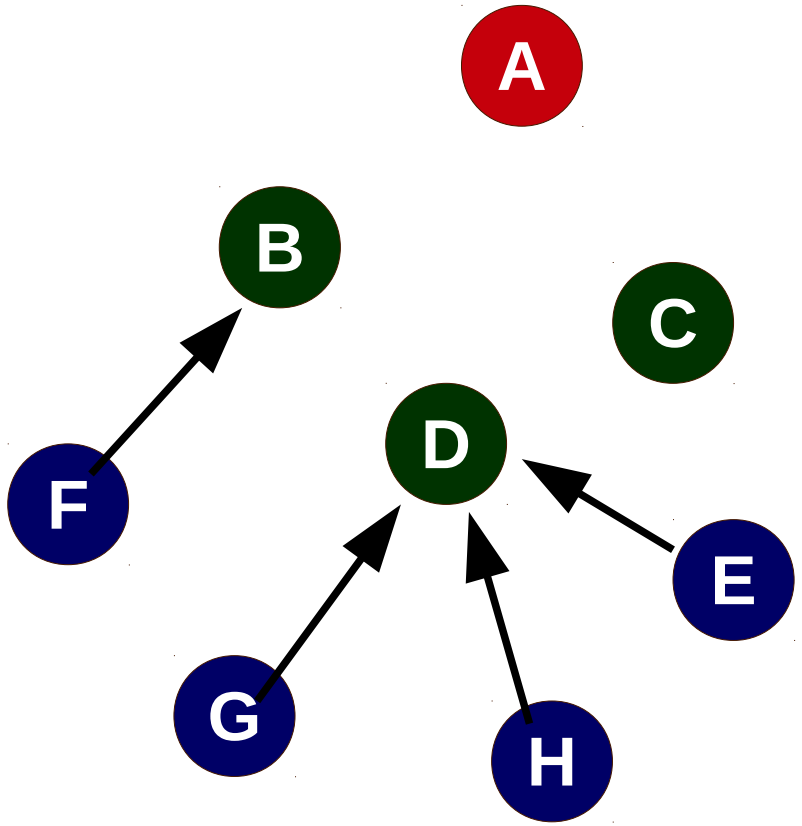
Mensagens enviadas quando solicitadas

ICMPv6 (+2 tipos e +3 opções)

RPL – Routing Protocol for Low-power and Lossy Networks



RPL – Routing Protocol for Low-power and Lossy Networks



Rank 32

Rank 128

Rank 256

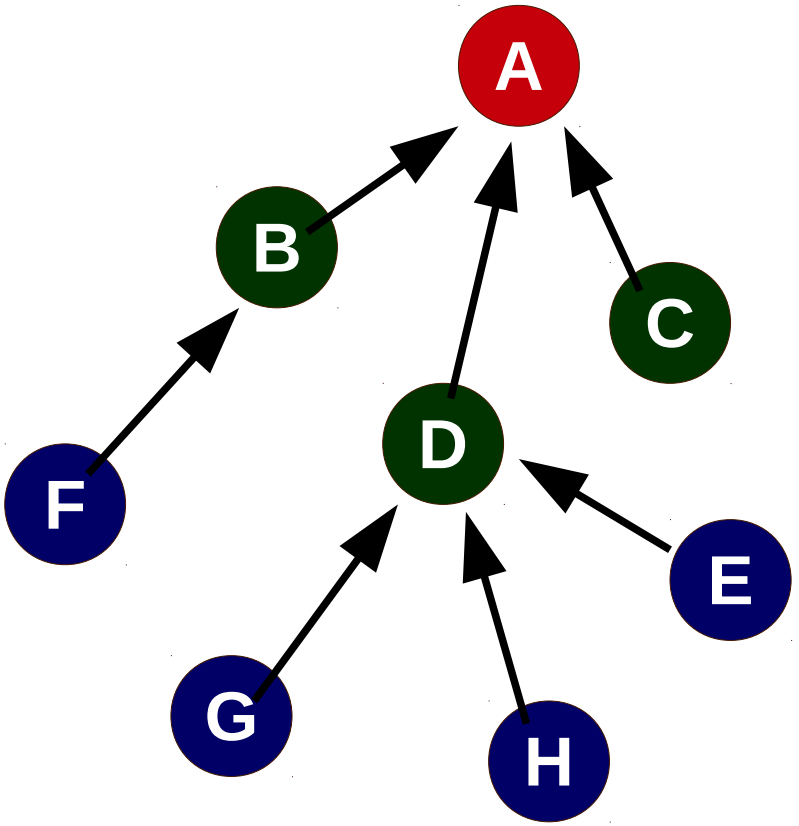
Árvore DODAG

Nó Sink

Mensagens:
- DIS
- DIO
- DAO

Trickle Algorithm

RPL – Routing Protocol for Low-power and Lossy Networks



Rank 32

Rank 128

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Árvore DODAG

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Mensagens:
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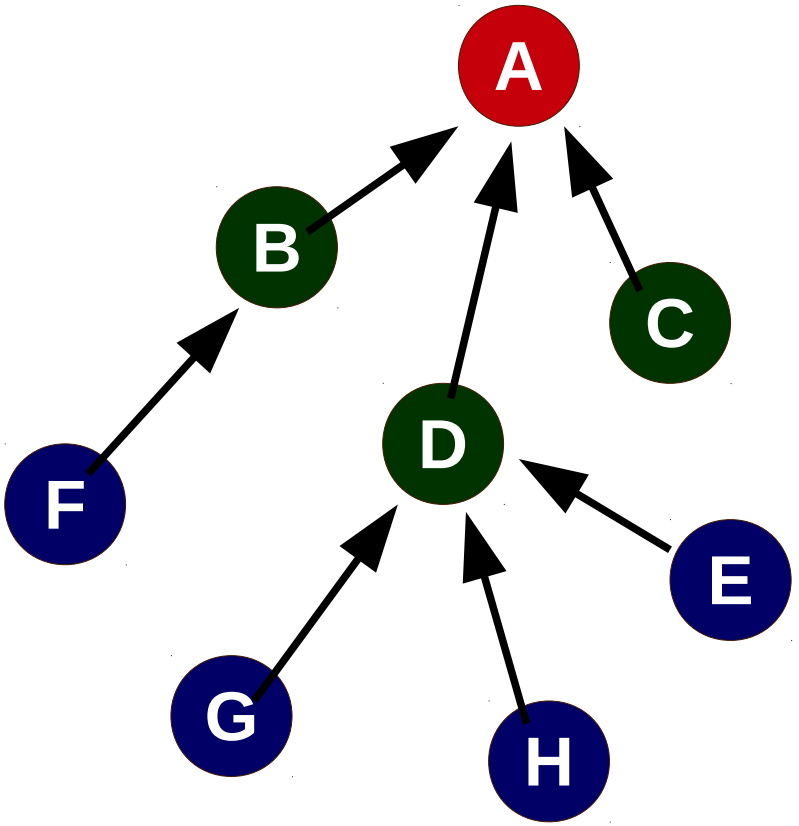
Trickle Algorithm

RPL – Routing Protocol for Low-power and Lossy Networks



Métricas:

- Energia
- Sobrecarga
- Throughput
- Latência
- Confiabilidade
- ...

Compressão do Cabeçalho UDP

Cabeçalho do Segmento UDP

64 bits = 8 bytes

Compressão do Cabeçalho UDP

Cabeçalho do Segmento UDP

64 bits = 8 bytes

Cabeçalho do Segmento HC_UDP

Min: 16 bits = 2 bytes

Compressão do Cabeçalho UDP

Cabeçalho do Segmento UDP

64 bits = 8 bytes

Cabeçalho do Segmento HC_UDP

Min: 16 bits = 2 bytes

Mensagem HTTP

```
GET /1 HTTP/1.1\r\n\r\n ...
```

Neste exemplo: 184 bytes

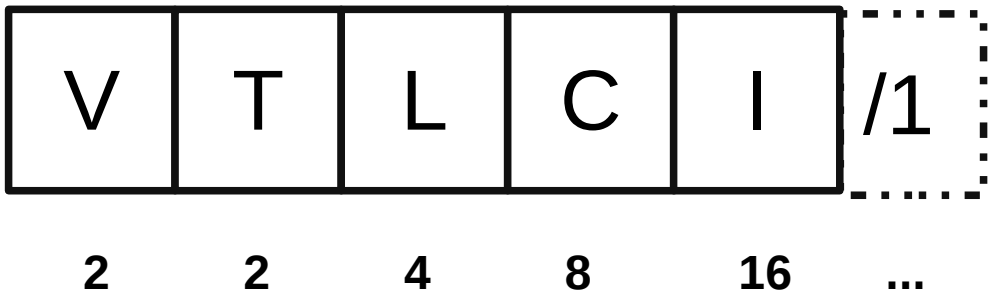
Aplicação com CoAP

Mensagem HTTP

GET /1 HTTP/1.1\r\n\r\n ...

Neste exemplo: 184 bytes

Mensagem CoAP (*Constrained Application Protocol)*



Neste exemplo: 6 bytes

Aplicação com CoAP

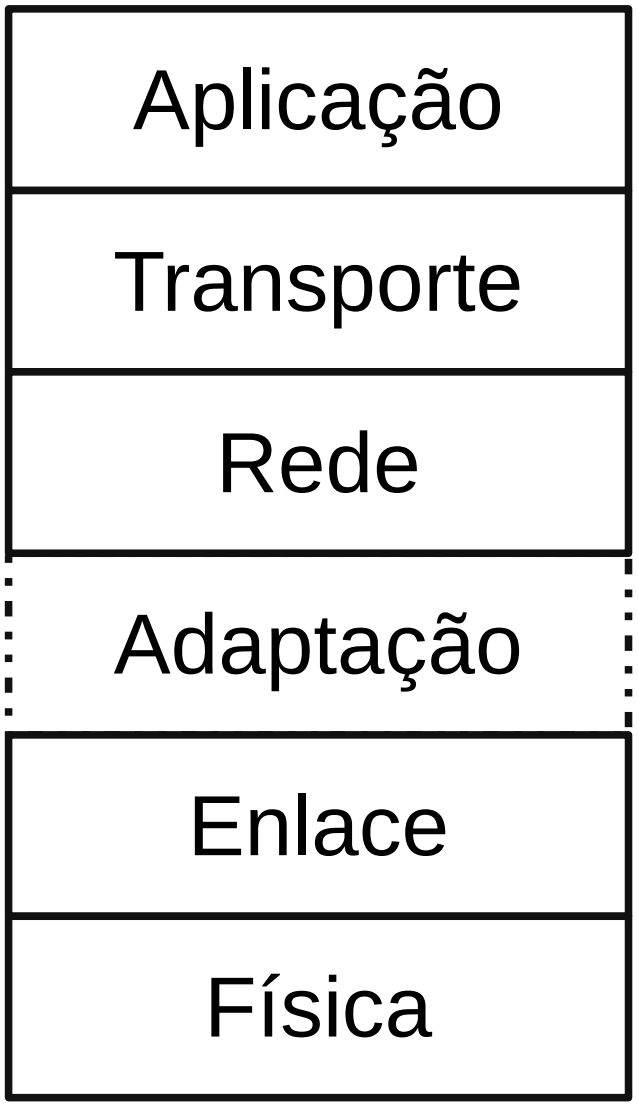
Levä et Al. - Experimento HTTP x CoAP

Pull Mode:

HTTP consumiu **duas** vezes mais energia que o CoAP

Push Mode:

HTTP consumiu **seis** vezes mais energia que o CoAP



DTLS

não

não

AES-CCM* - 32, 64, 128 bits

6LoWPAN

- Grupo concluído
- **6lo** - IPv6 over Network of Resource-constrained Nodes
  → IEEE 802.15.4
  → BT-LE (Bluetooth Low Energy)
  → NB-PLC (Narrowband Power Line Communications)
  → Ultra Lower Energy DECT
  → ITU-T G.9959

Outros Grupos:

ROLL → Protocolo RPL
CoRE → Protocolo CoAP
6TiSCH → Subcamada de adaptação 802.15.4e TSCH

Mercado (exemplos)

Libelium.com:

Sensores Gases

Sensor estacionamento

Agricultura

6LoWPAN Radio

Wigwag.com:

Segurança

- Gerenciamento de troca de chaves
- Ataques
- Mitigação
- Sistemas de Detecção de Intrusão

Perguntas?

UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

Grato :)

pereira@hermano.com.br

Fontes:

[1] J. Tan and S. Koo, “A Survey of Technologies in Internet of Things,” in Distributed Computing in Sensor Systems (DCOSS), 2014 IEEE International Conference on, May 2014, pp. 269–274.

[2] D. Evans, “The Internet of Things - How the Next Evolution of the Internet Is Changing Everything,” in Cisco White Paper, Apr 2011.

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[10] G. Montenegro, N. Kushalnagar, J. Hui, and D. Culler, “Transmission of IPv6 Packets over IEEE 802.15.4 Networks,” RFC 4944 (Proposed Standard), Internet Engineering Task Force, Sep. 2007, updated by RFCs 6282, 6775. [Online]. Available: http://www.ietf.org/rfc/rfc4944.txt

[11] S. Deering and R. Hinden, “Internet Protocol, Version 6 (IPv6) Specification,” RFC 2460 (Draft Standard), Internet Engineering Task Force, Dec. 1998, updated by RFCs 5095, 5722, 5871, 6437, 6564, 6935, 6946, 7045, 7112. [Online]. Available: http://www.ietf.org/rfc/rfc2460.txt

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