Computer Networking

Data-link layer

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Data Link Layer

Our goals:

- Understand principles behind data link layer services:
  - sharing a broadcast channel: multiple access
  - link layer addressing
  - LAN interconnection
- Instantiation and implementation of various link layer technologies

Overview:

- Link layer services
- Point-to-point protocol
  - PPP
- Later on:
  - LANs:
    - Ethernet
    - 802.11
  - link layer addressing, ARP
  - LAN interconnection
    - hubs, bridges, switches

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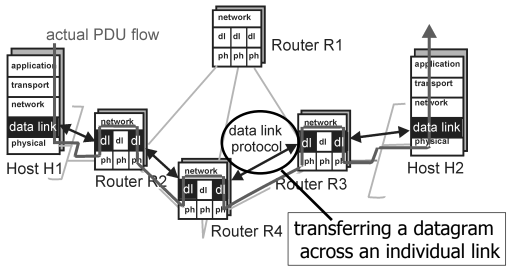
Link Layer: setting the context



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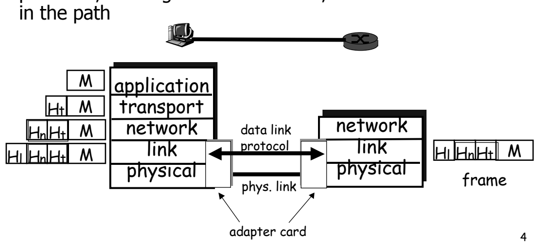
Link Layer: setting the context

- two *physically connected* devices:
  - host-router, router-router, host-host
- unit of data: *frame (trame)*
- a datagram may be handled by different link-layer protocols, offering different services, on the different links in the path



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Link Layer Services

- Framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - implement channel access if shared medium,
  - 'physical addresses' used in frame headers to identify source, dest
    - different from IP address!
- Reliable delivery between two physically connected devices:
  - we learned how to do this already (cf. Transport Layer)
  - seldom used on low bit error link (fiber, some twisted pair)
  - wireless links: high error rates
    - link-level reliability to avoid end-end retransmission

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Link Layer Services (more)

- Flow Control
  - pacing between sender and receivers
- Error Detection
  - errors caused by signal attenuation, noise.
  - receiver detects presence of errors:
    - signals sender for retransmission or drops frame
- Error Correction
  - receiver identifies *and corrects* bit error(s) without resorting to retransmission
- Half-duplex and full-duplex

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Generating polynomes

- CCITT
  - $g(x) = x^{16} + x^{12} + x^5 + 1$
    - detectes all simple errors, doubles, odd number of errors, bursts of 16 and less, 99.997% of 17, 99.998% of 18 or more
  - $g(x) = x^{16} + x^{15} + x^2 + 1$
- Ethernet
  - $g(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$

Examples of protocols

- CRC - *Cyclic Redundancy Check*
- X.25 - LAPB

address	control	data	CRC
8 bits	8 bits	variable	16 bits

- Ethernet

dest	source	type	data	CRC
6 bytes	6 bytes	2 bytes	46 - 1500 bytes	4 bytes

Error detection in TCP/IP

- *Checksum TCP/IP*
  - sum of 16 bit words with carry in 1's complement
  - carry is added
  - 1's complement
- Characteristics
  - detects all simple errors
  - if data uniformly distributed, residual error rate 1/65536

Example

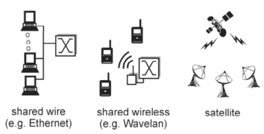
7 bit words:

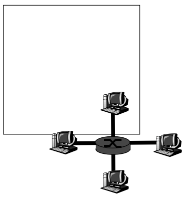
```
 0000010
 1011011
 1101100
 0000011
 -------
11001100
       1
 -------
 1001101
 0110010
```


Multiple Access Links and Protocols

Three types of “links”:

- point-to-point (single wire, e.g. PPP)
- broadcast (shared wire or medium; e.g, Ethernet, 802.11)





- NBMA - Non Broadcast Multiple Access (ATM, X.25)

Point to Point Data Link Control

- One sender, one receiver, one link: easier than a broadcast link:
  - no Media Access Control
  - no need for explicit MAC addressing
  - e.g., dialup link, ISDN line
- Popular point-to-point DLC protocols:
  - PPP (point-to-point protocol)
  - HDLC: High level data link control (Data link used to be considered “high layer” in protocol stack!)

PPP *(Point-to-Point Protocol)*

- Point to point data link
  - dial-up (modem) connexions, fiber (SONET/SDH)
- Data framing, error detection
- Transparent data transmission
  - avoid transmitting characters interpreted by the modem
- Data
  - multi-protocol: IP packets, IPX packets, others
- Header compression - IP, TCP
- Authentication

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Associated protocols

- LCP *(Link Control Protocol)*
  - activate a link
  - negociate options
  - test
- IPCP *(IP Control Protocol)*
  - network layer address negotiation:
    - hosts/nodes across the link must learn/configure each other's network address
- PAP *(PPP Authentification Protocol)*
  - password exchange

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Associated protocols

- CHAP *(Challenge Handshake Authentication Protocol)*
  - server sends a challenge (random number)
  - dial-up host encrypts it using a common secret password
  - sends the results
  - server does the same and compares
  - call NCP *(Network Control Protocol)* to finish with network level configuration
- NCP *(Network Configuration Protocol)*
  - network layer negotiation
  - depends on the network protocol
- IPCP *(IP Configuration Protocol)*
  - NCP for IP: configure the network layer
  - address negotiation
    - assign a temporary IP address to dial-up host
  - decide whether to use IP/TCP header compression

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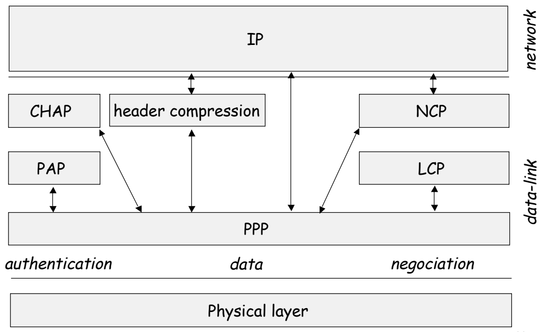
Protocols



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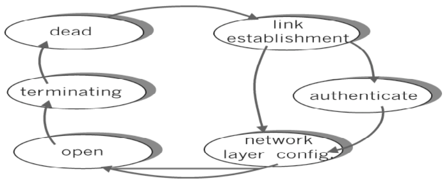
PPP data control protocol

- PPP-LCP establishes/releases the PPP connection; negotiates options
- Starts in DEAD state
- Options: max frame length; authentication protocol, call-back
- Once PPP link established, IPCP moves in (on top of PPP) to configure IP network addresses etc.



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Data framing

- Frame format inherited from first packet switching networks
  - synchronous transmission with error recovery (HDLC)
  - Transpac (X.25 LAPB)
- PPP
  - start and end of frame delimitation
  - transparent data transmission
    - how to transmit characters used for delimitation?
    - byte stuffing
  - error detection - polynomial code

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PPP - frame formats

flag	address	control	protocol	data	CRC	flag
8 bits	8 bits	8 bits	8 or 16 bits	variable	16 bits	8 bits

- Flag: 01111110 - **0x7e**
- Address: 11111111
- Control: 00000011
- Protocol: LCP, IPCP, IP
- Data: 1500 bytes by default
- CRC: 16 bit CCITT polynomial code

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PPP - frame formats

flag	address	control	protocol	data	CRC	flag
8 bits	8 bits	8 bits	8 or 16 bits	variable	16 bits	8 bits

- Transparent transmission - Byte stuffing
  - 0x7e 0x7d 0x5e
  - 0x7d 0x7d 0x5d
  - character X < 0x20 0x7d 0xYY
  - 0xYY = X + 0x20
  - example : 0x03 0x7d 0x23

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Example PPP connection (logs)

```
▪ PPPoE connecting to service
▪ PPPoE connection established.
▪ Connect: ppp0 <--> socket[34:16]
▪ sent [LCP ConfReq id=0x1 <mru 1492> <asyncmap 0x0>
  <magic 0x1f3f807b> <pcomp> <accomp>]
▪ rcvd [LCP ConfReq id=0x81 <mru 1500> <auth chap MD5>
  <magic 0x4b4dcf02>]
▪ sent [LCP ConfAck id=0x81 <mru 1500> <auth chap MD5>
  <magic 0x4b4dcf02>]
▪ rcvd [LCP ConfRej id=0x1 <asyncmap 0x0> <pcomp>
  <accomp>]
▪ sent [LCP ConfReq id=0x2 <mru 1492> <magic
  0x1f3f807b>]
```

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Example PPP connection

```
▪ rcvd [LCP ConfAck id=0x2 <mru 1492> <magic
  0x1f3f807b>]
▪ sent [LCP EchoReq id=0x0 magic=0x1f3f807b]
▪ rcvd [CHAP Challenge id=0x1
  <1a5c7a4446bf4a51bc15b170dfbb66ae>, name =
  "BSGRE102"]
▪ ChapReceiveChallenge: rcvd type CHAP-DIGEST-MD5
▪ sent [CHAP Response id=0x1
  <2c99f036ee3190e0364d6bad10e4b971>, name =
  "monlogin@isp"]
▪ rcvd [LCP EchoRep id=0x0 magic=0x4b4dcf02]
▪ rcvd [LCP ConfReq id=0x12 <auth pap> <magic
  0x794cb2ad>]
▪ sent [LCP ConfReq id=0x3 <mru 1492> <asyncmap 0x0>
  <magic 0x5893ae1e> <pcomp> <accomp>]
▪ lcp_reqci: returning CONFACK.
```

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Example PPP connection

```
▪ sent [LCP ConfAck id=0x12 <auth pap> <magic
  0x794cb2ad>]
▪ rcvd [LCP ConfNak id=0x3 <mru 1500>]
▪ sent [LCP ConfReq id=0x4 <asyncmap 0x0> <magic
  0x5893ae1e> <pcomp> <accomp>]
▪ rcvd [LCP ConfAck id=0x4 <asyncmap 0x0> <magic
  0x5893ae1e> <pcomp> <accomp>]
▪ sent [LCP EchoReq id=0x0 magic=0x5893ae1e]
▪ sent [PAP AuthReq id=0x1 user="monlogin@isp"
  password=<hidden>]
▪ rcvd [LCP EchoRep id=0x0 magic=0x794cb2ad]
▪ rcvd [PAP AuthAck id=0x1 ""]
▪ sent [IPCP ConfReq id=0x1 <addr 0.0.0.0> <compress
  VJ 0f 01>]
▪ rcvd [IPCP ConfReq id=0x48 <addr 192.168.254.254>]
▪ ipcp: returning Configure-ACK
```

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Example PPP connection

```
▪ sent [IPCP ConfAck id=0x48 <addr 192.168.254.254>]
▪ rcvd [IPCP ConfRej id=0x1 <compress VJ 0f 01>]
▪ sent [IPCP ConfReq id=0x2 <addr 0.0.0.0>]
▪ rcvd [IPCP ConfNak id=0x2 <addr 82.65.101.110>]
▪ sent [IPCP ConfReq id=0x3 <addr 82.65.101.110>]
▪ rcvd [IPCP ConfAck id=0x3 <addr 82.65.101.110>]
▪ ipcp: up
▪ local  IP address 82.65.101.110
▪ remote IP address 192.168.254.254
```

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Example PPP connection (traces)

- Point-to-Point Protocol
- Address: 0xff
- Control: 0x03
- Protocol: IP (0x0021)
- Internet Protocol, Src Addr: 62.147.72.195 (62.147.72.195), Dst Addr: 129.88.38.1 (129.88.38.1)
- Protocol: TCP (0x06)
- Transmission Control Protocol, Src Port: 53475 (53475), Dst Port: ssh (22), Seq: 1928148501, Ack: 0, Len: 0

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Example PPP connection (traces)

- Point-to-Point Protocol
- Address: 0xff
- Control: 0x03
- Protocol: IP (0x0021)
- Internet Protocol, Src Addr: 129.88.38.1 (129.88.38.1), Dst Addr: 62.147.72.195 (62.147.72.195)
- Protocol: TCP (0x06)
- Transmission Control Protocol, Src Port: ssh (22), Dst Port: 53475 (53475), Seq: 1558034509, Ack: 1928148502, Len: 0

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Not provided by PPP

- error correction/recovery
- flow control
- sequencing

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Data Link Layer: Summary

- Principles behind data link layer:
  - structure the information sent over the wire
    - frame structure
  - may add some functions
    - TCP/IP: error and flow control done at upper layers
  - using a link between two connected devices
    - point-to-point
    - sharing a broadcast channel
- PPP
  - used in many contexts
    - modems, ADSL, POS
  - authentication and accounting

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