KTH ROYAL INSTITUTE
OF TECHNOLOGY

Lecture #9
Introduction to communication networks

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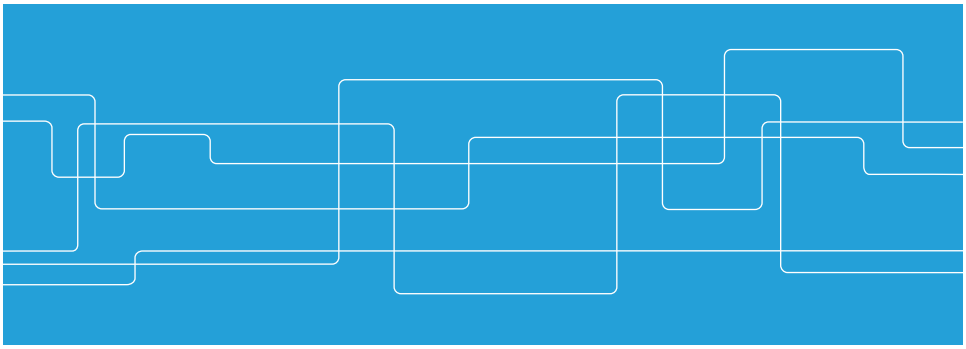


In this series…

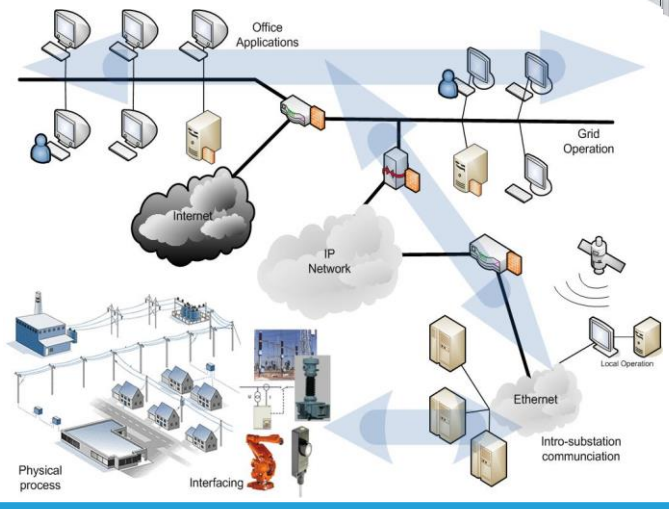
- Lecture #9
  - Communication protocol basics
  - The OSI model
  - Relationship between OSI and SGAM
  - **Hands-on exercise**: Wireshark and HTTP
- Lecture #10
  - OSI model – physical layer
  - Topologies
  - Media Access Control
  - Routing
  - TCP/IP
  - Exercise: Traceroute, ping and Wireshark

In this series…

- Lecture #11
  - Power systems communication
  - Wireshark exercises
- Lecture #12
  - Delay & Jitter
  - Quality-of-Service
  - Loss and Throughput
  - Time synchronization
  - Project assignment Q&A

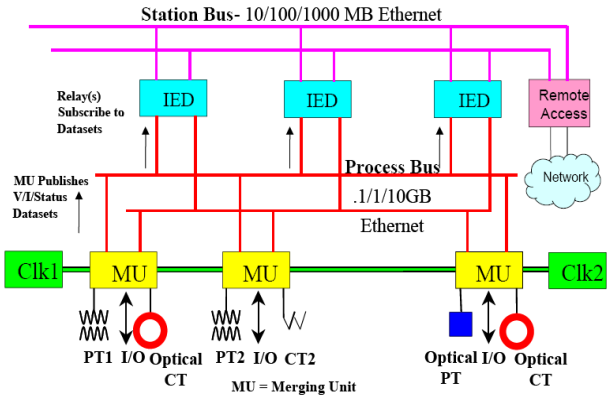
Recap

Computers and Networks in Power Systems



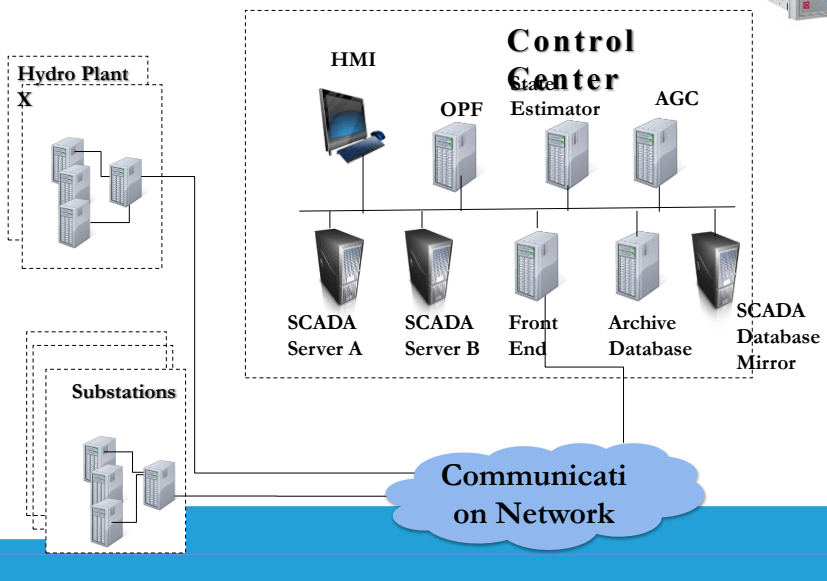
Recap

Substation Networks



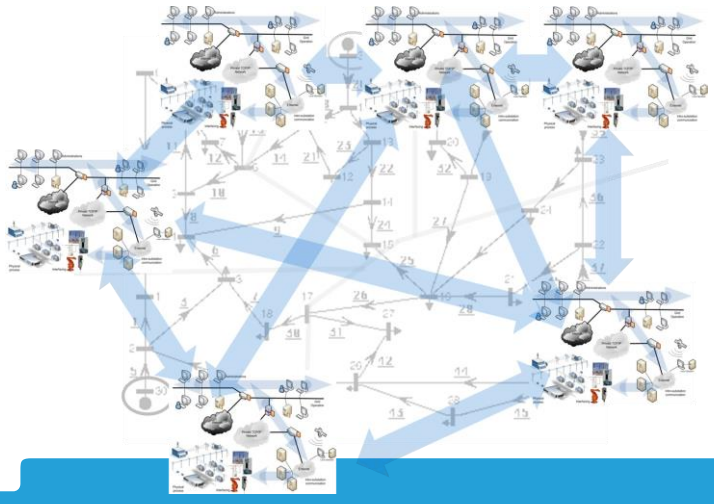
Recap

SCADA Networks



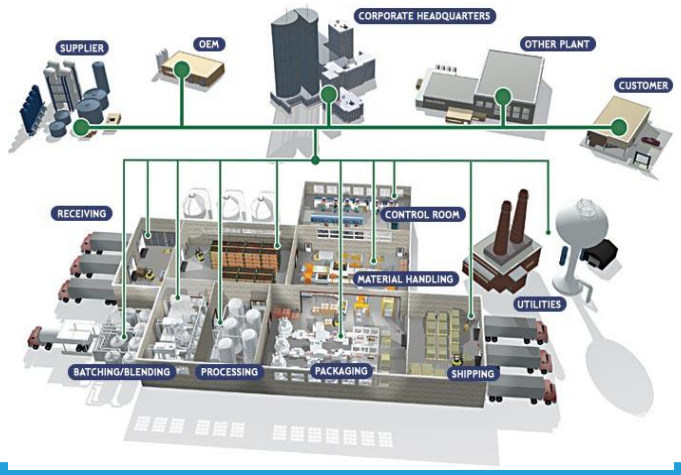
Recap

SCADA Networks



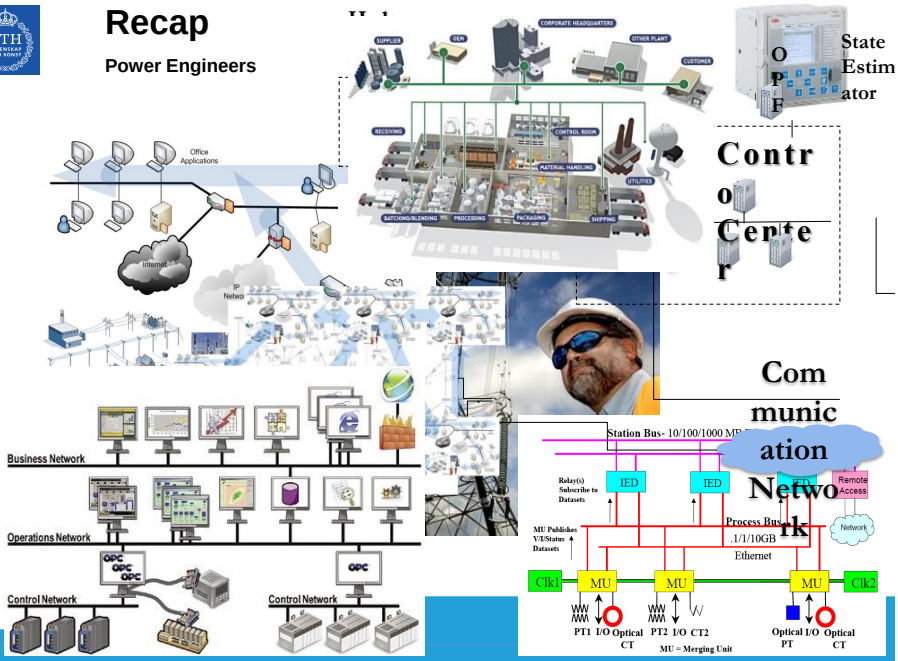
Recap

Integrated Networks



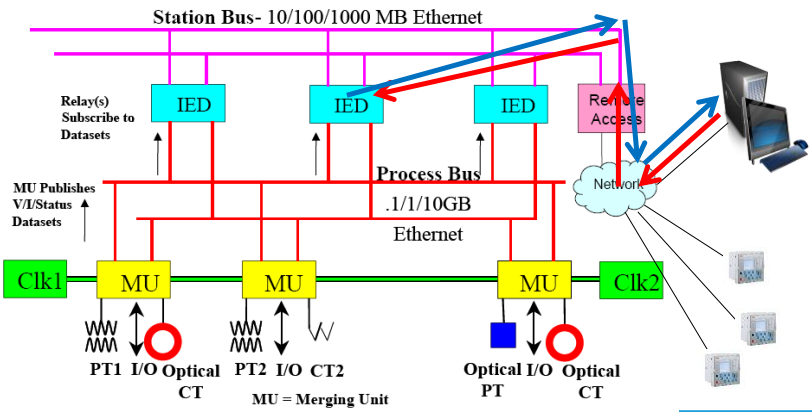
Recap

Power Engineers



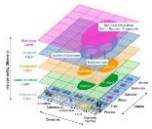
Recap

Modern substation

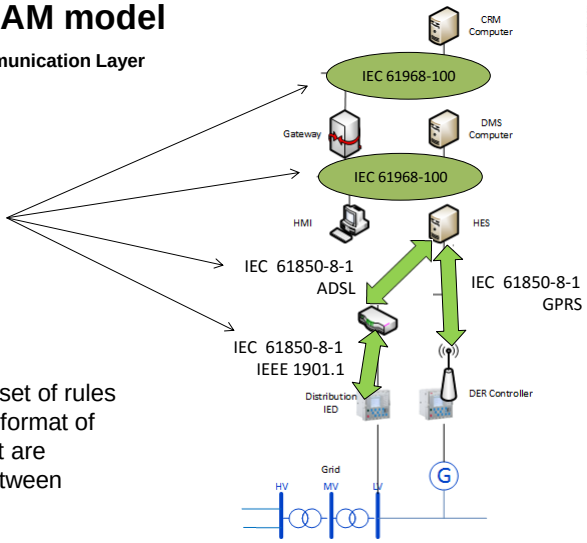


SGAM model

Communication Layer

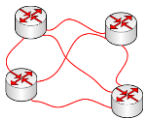


Protocols!



Dictionary:
Computers. a set of rules governing the format of messages that are exchanged between computers.

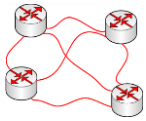
Protocol Basics

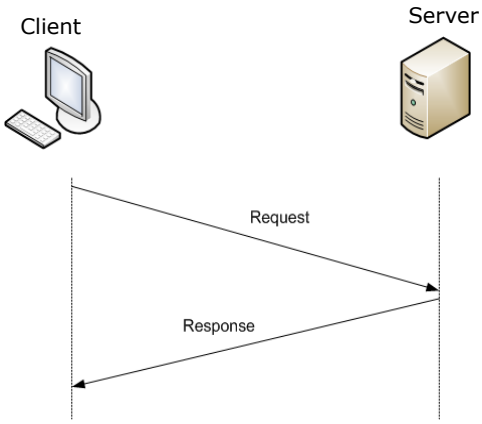


Basic Protocol
HTTP protocol – example
Wireshark
Some observations from the example

Protocol Basics

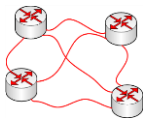
Basic protocol





Protocol Basics

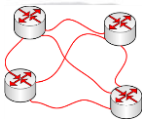
Basic protocol

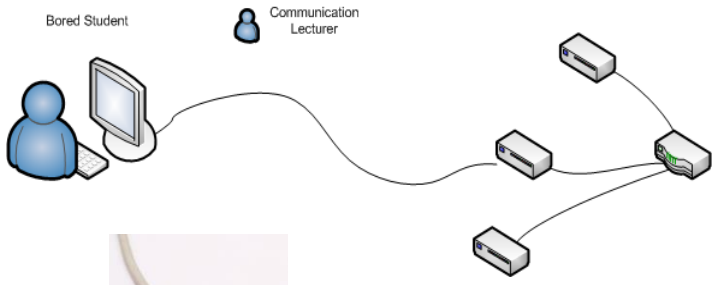


We use these continuously!

Protocol Basics

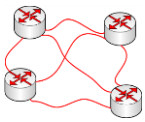
HTTP protocol

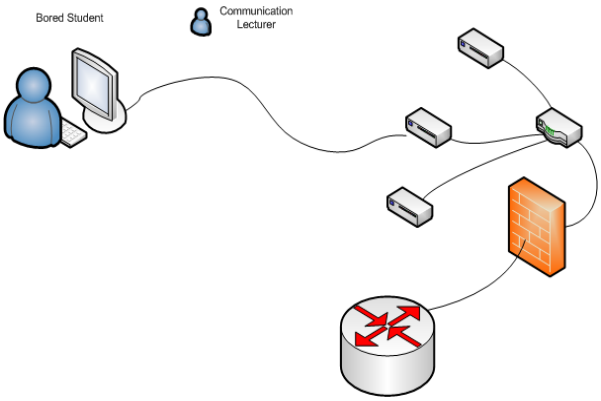




Protocol Basics

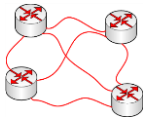
HTTP protocol

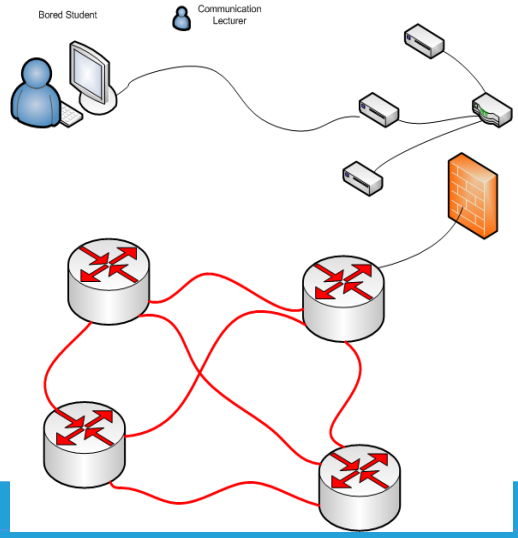




Protocol Basics

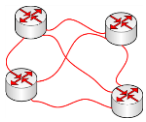
HTTP protocol

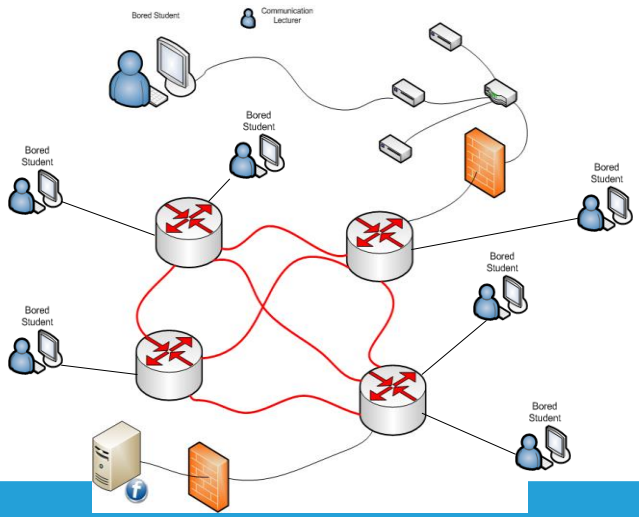




Protocol Basics

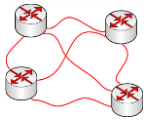
HTTP protocol





Protocol Basics

HTTP protocol

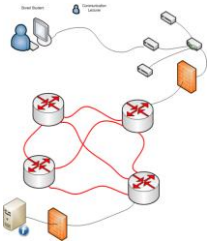


What program/application does the student use to access the service?

- An application that implements the protocol - browser

How is the desired service identified?

- URL - Uniform Resource Locator



How does the student request information?

- HTTP GET message

How does the student host know where to send the request?

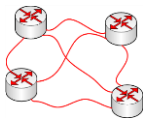
- IP address
- Routing table

What carries the message to the service provider?

- Network infrastructure – LAN -> Internet (WAN)

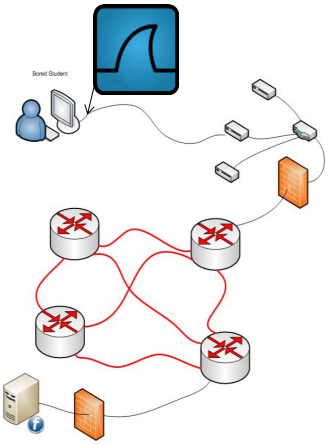
Communication Networks

Wireshark



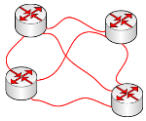
Example using Wireshark:

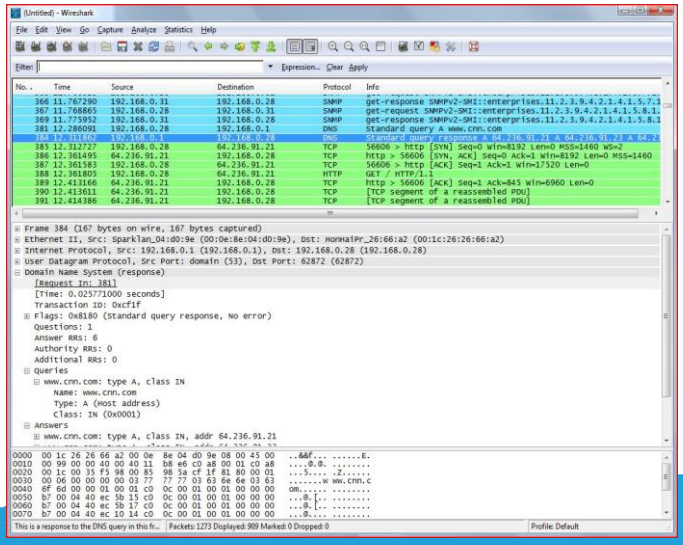
- Set Wireshark filter to only capture HTTP
- Start the recording
- Request the service (a website in this case)
- Watch the capture
- Stop the capture when complete
- Analyse the results



Communication Networks

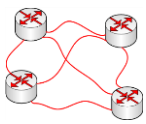
DNS protocol - example





Communication Networks

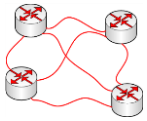
Wireshark



```
Frame 384 (167 bytes on wire, 167 bytes captured)
Ethernet II, Src: Sparklan_04:d0:9e (00:0e:8e:04:d0:9e)
Internet Protocol, Src: 192.168.0.1 (192.168.0.1), Dst
User Datagram Protocol, Src Port: domain (53), Dst Port
Domain Name System (response)
    [Request In: 381]
    [Time: 0.025771000 seconds]
    Transaction ID: 0xcf1f
  Flags: 0x8180 (Standard query response, No error)
    Questions: 1
    Answer RRs: 6
    Authority RRs: 0
    Additional RRs: 0
  Queries
    www.cnn.com: type A, class IN
        Name: www.cnn.com
        Type: A (Host address)
        Class: IN (0x0001)
  Answers
    www.cnn.com: type A, class IN, addr 64.236.91.21
```

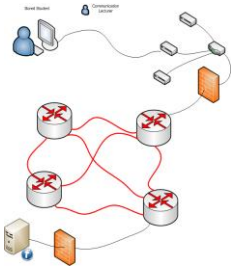
Protocol Basics

Some observations from the HTTP protocol example

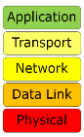


Some observations:

- Often need multiple services to access the desired service
- eg. DNS translates hostname in URL to IP-address and
- HTTP is used to fetch the webpage data
- There appear to be layers in the protocols
- Some of the layers are common even when different application-layer services are used eg. Ethernet, IP…
- There are some containers used:
  - Datagram
  - Packet
  - Frame
- Identification of host, service, source, destination:
  - MAC `00:0e:8e:04…`
  - IP `192.168.0.1`
  - Port `80 (HTTP)`



The OSI model



Layering

OSI model – long version

OSI model – short version

Headers

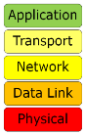
OSI layers

- Application layer
- Transport layer
- Network layer
- Data link layer
- Physical layer

Transition between layers

The OSI model

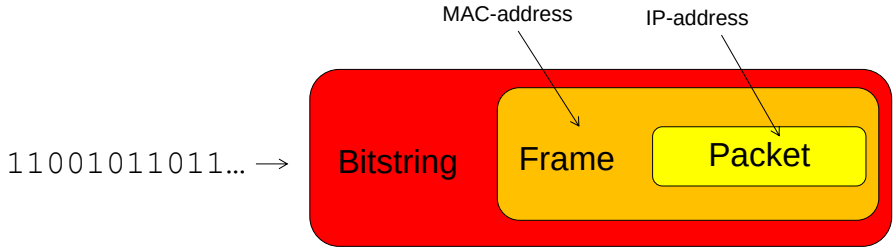
Layering



Is NOT the SGAM model, be aware of the distinction.

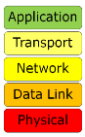
Each layer encapsulates the container of the layer above

Identification and addressing information for each layer



The OSI model

Layering



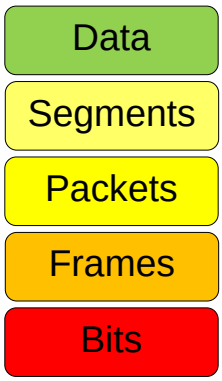
Units of high-level **protocol data** eg. HTML

Data is **segmented**, sometimes into streams (TCP) or “datagrams” (UDP)

Each segment is **packaged** to be sent across a network.

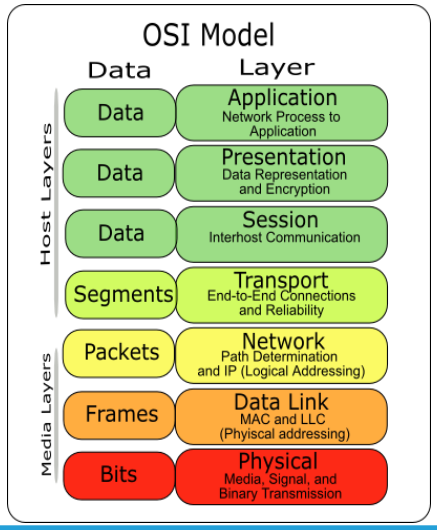
The package is enclosed in a **frame** to be sent on the **link** eg. Ethernet

The frame is transmitted as a string of **binary bits** on the physical media eg. UTP



The OSI model

Application
Transport
Network
Data Link
Physical

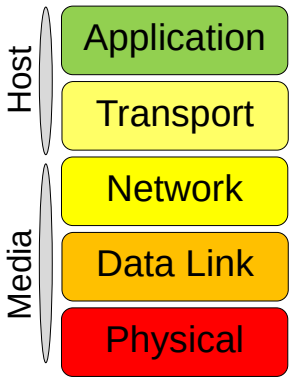


The OSI model

Short version

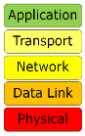
Application
Transport
Network
Data Link
Physical

- Session and Presentation layers viewed as application-internal and are not modeled
- Lower 3 layers part of network infrastructure.
  - More generalized
- Top layers mainly associated with host-host applications.
  - Application specific eg. HTTP



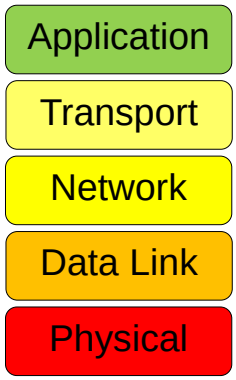
The OSI model

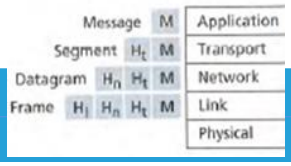
Headers



Additional information for each OSI layer:

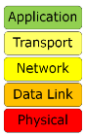
- Contained in **headers:**
  - **Transport**
    - Source/destination port
    - …
  - **Network**
    - Source/destination IP address
    - …
  - **Data Link**
    - Source/destination MAC address
    - …



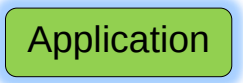


The OSI model

Application layer



Application protocols like
- HTTP
- FTP
- SSH



In power systems:
- MMS (IEC 61850-8-2)
- IEC 60870-5-104 (an RTU protocol over IP)

More about this later…

The OSI model

Transport layer

Application
Transport
Network
Data Link
Physical

Transport layer protocols include:

- Transmission Control Protocol (streams)
- User Datagram Protocol (datagrams)

Transport

– **TCP header fields**
  - Source/destination port
  - Sequence number
  - Acknowledgement (Ack) number
  - Window size
  - Checksum
  - Options

TCP Header

Bit offset	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	Source port																Destination port															
32	Sequence number																															
64	Acknowledgment number																															
96	Data offset				Reserved			CWR	ECE	URG	ACK	PSH	RST	SYN	FIN		Window Size															
128	Checksum																								Urgent pointer							
160 …	Options (if Data Offset > 5) …																												padding			

The OSI model

Network layer

Application
Transport
Network
Data Link
Physical

Routing of packets at this layer

- A router forwards packets toward destination
- Internet Protocol

Network

– **IP header fields**
  - Source/destination IP address
  - Time-to-live – prevents immortal lost packets
  - Unique ID
  - Checksum
  - Options

bit offset	0–3	4–7	8–13	14,15	16–18	19–31
0	Version	Header Length	Differentiated Services Code Point	Explicit Congestion Notification	Total Length	
32	Identification				Flags	Fragment Offset
64	Time to Live		Protocol		Header Checksum	
96	Source IP Address					
128	Destination IP Address					
160	Options (if Header Length > 5)					
160 or 192+	Data					

The OSI model

Data Link layer

Application
Transport
Network
Data Link
Physical

Transfer data between adjacent nodes on a link

Data Link

- Do not cross boundary of a local network

- Media Access Control (MAC)
- Logical Link Control (LLC)

  – **Ethernet frame header**
    - Preamble
    - Source/destination MAC address
    - Acknowledgement (Ack) number
    - Payload size
    - Cyclic redundancy check (CRC)
    - 12-octet interframe gap

802.3 Ethernet frame structure

Preamble	Start of frame delimiter	MAC destination	MAC source	802.1Q tag (optional)	Ethertype or length	Payload	Cyclic redundancy check	Interframe gap
7 octets of 10101010	1 octet of 10101011	6 octets	6 octets	(4 octets)	2 octets	46–1500 octets	4 octets	12 octets
		64–1522 octets						
72–1530 octets								
84–1542 octets								

The OSI model

Data Link layer – Media Access Control (MAC)

Application
Transport
Network
Data Link
Physical

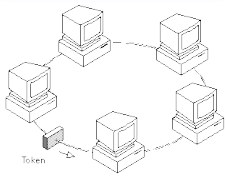
Data Link

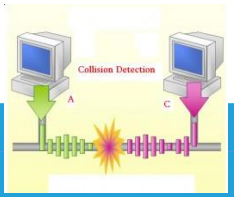
- Determines who gets access to the medium

  - Token passing
    - Whoever **has the token** can send

  - Carrier Sense Multiple Access (CSMA)
    - **Listens** whether someone is sending

  - Collision Detection (CD)
    - Bits transmitted on the medium collide
    - Collision needs to be resolved





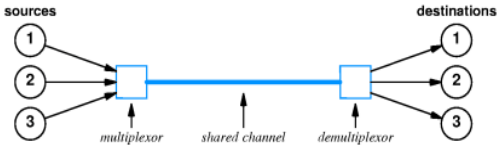
The OSI model

Data Link layer – Logical Link Control (LLC)

Application
Transport
Network
Data Link
Physical

- **Multiplexing** network layer packets
- Error handling in some link layer protocols

Data Link



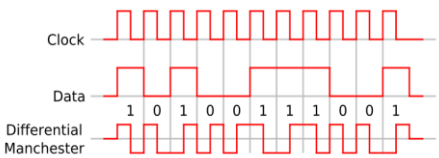
The OSI model

Physical layer

Application
Transport
Network
Data Link
Physical

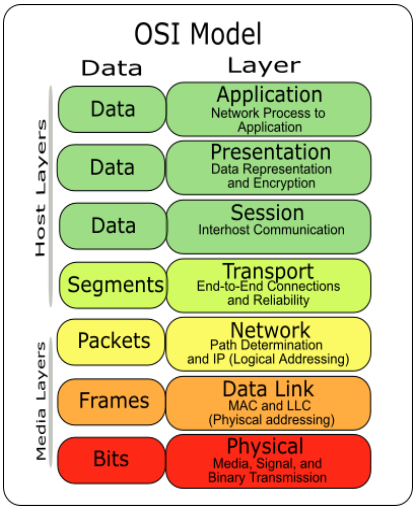
- Bit-by-bit delivery
- Specifies
  - Medium (guided/unguided) - Cable/Fibre/Radio
    - Connector types
    - Cable length
  - Signal characteristics
    - Voltage
    - Frequency of carrier signal
    - Impedence
  - Line coding
    - Tuned for physical channel
    - For modulation
  - Signalling
    - Start/stop

Physical



The OSI model

Application
Transport
Network
Data Link
Physical



⋮

Layer 3

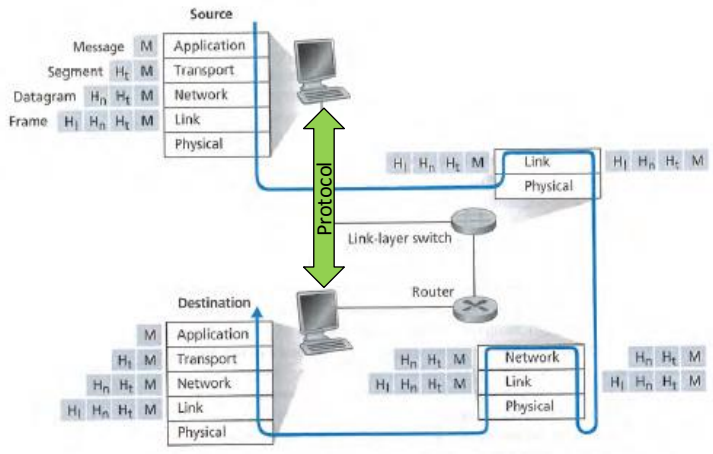
Layer 2

Layer 1

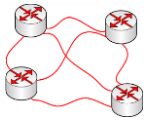
The OSI model

Transition between layers

Application
Transport
Network
Data Link
Physical



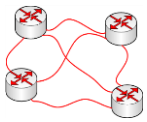
Circuit and Packet Switching



Circuit switching
Packet switching

Circuit and Packet Switching

Circuit Switching



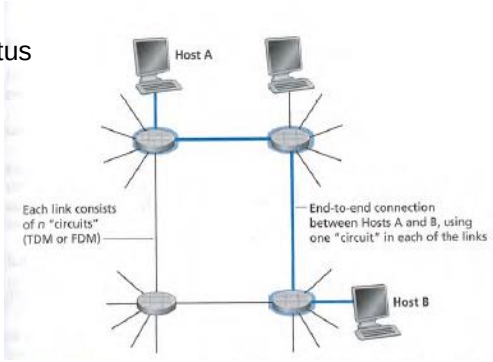
Like an old telephone network

Fixed connection
- Follows same route
- Routers need to maintain status

Handshake required
- TCP does this

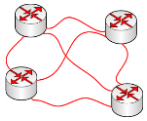
Allows for host flow control

Reliable delivery



Circuit and Packet Switching

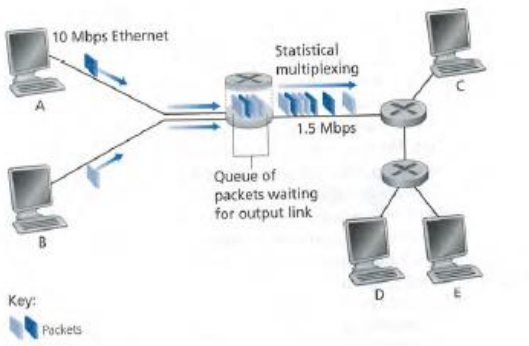
Packet Switching



Like the postal service

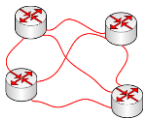
No connections
- Follows stochastic route
- Stateless routers

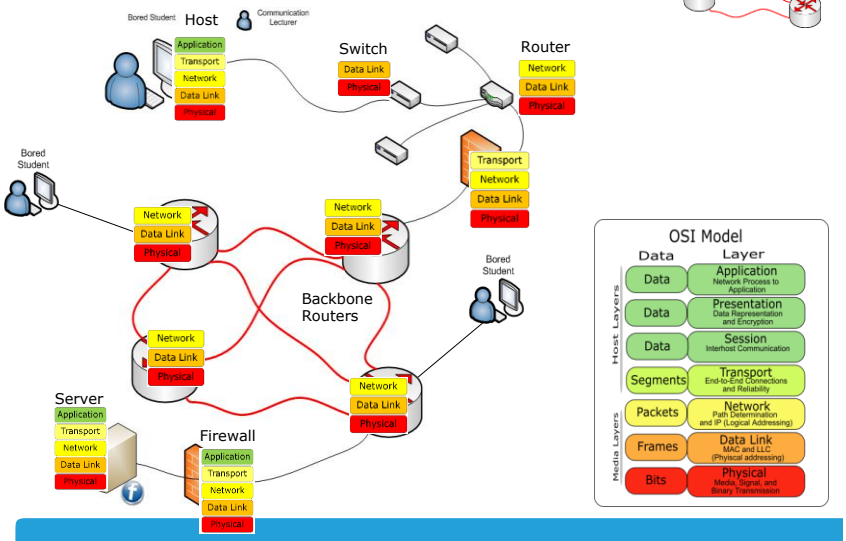
- IP is packet switched
- Most link-layer protocols



Communication Networks

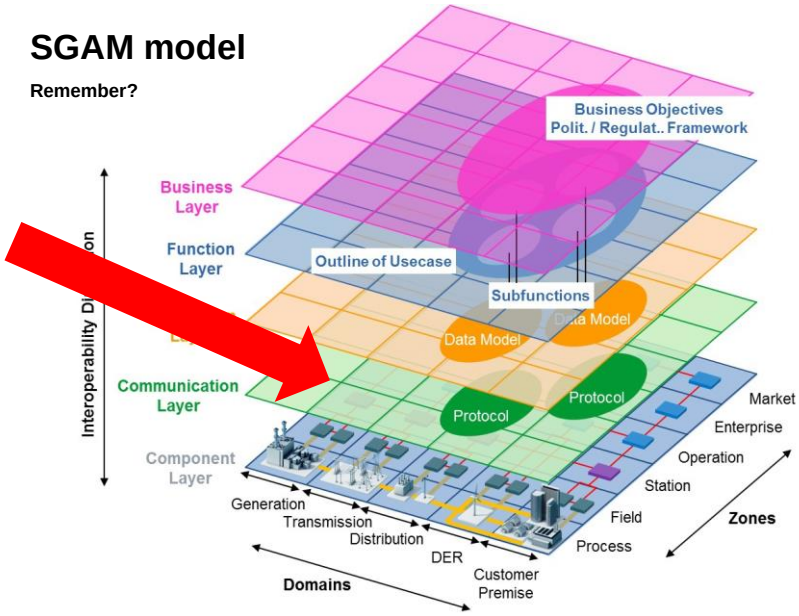
Recap of example





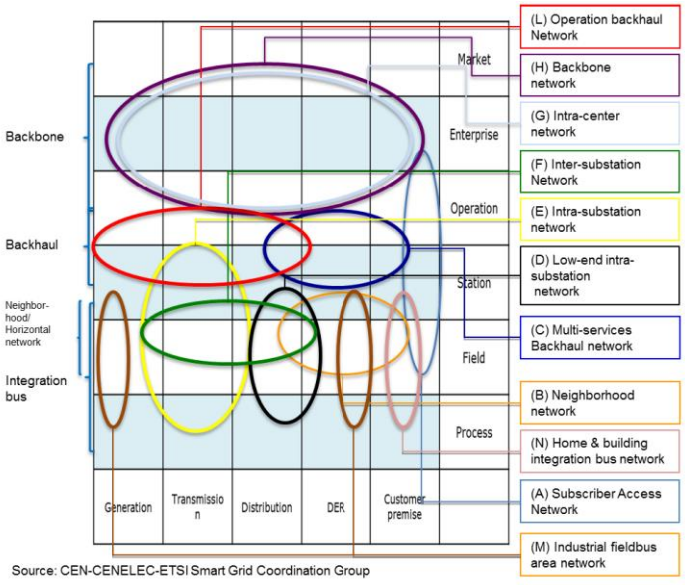
SGAM model

Remember?



SGAM model

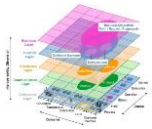
Communication Layer

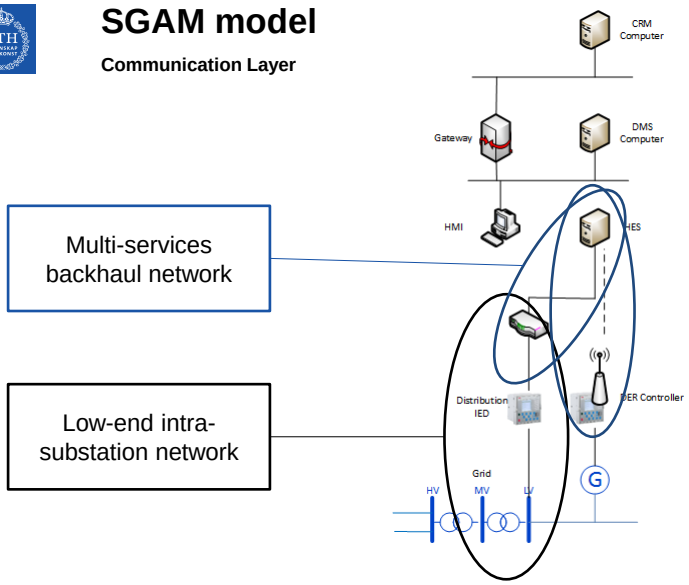


Source: CEN-CENELEC-ETSI Smart Grid Coordination Group

SGAM model

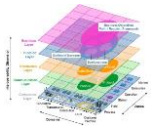
Communication Layer

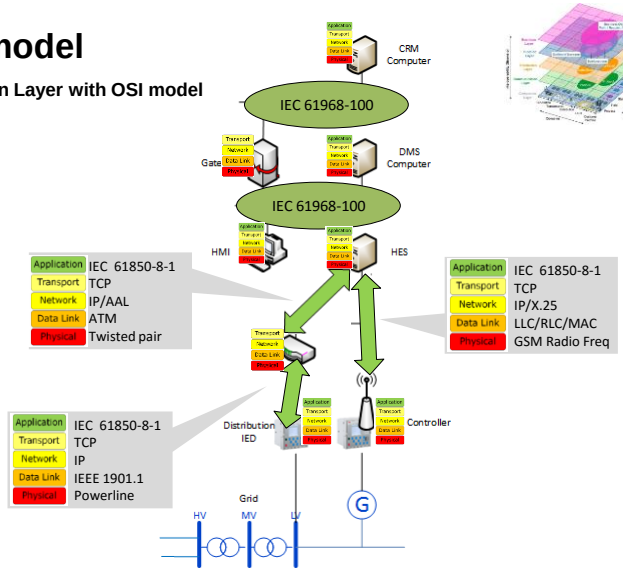




SGAM model

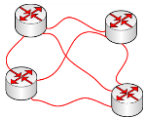
Communication Layer with OSI model





Class exercise

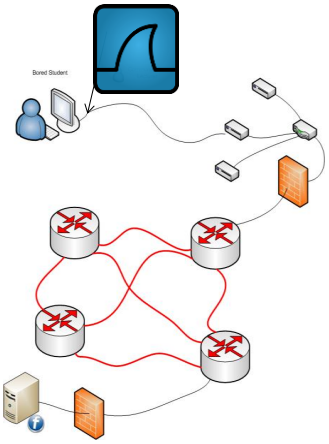
Wireshark



Install Wireshark: https://www.wireshark.org/

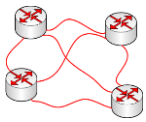
Example using Wireshark:

- Set Wireshark filter to only capture HTTP
- Start the recording
- Request the service (a website in this case)
- Watch the capture
- Stop the capture when complete
- Analyse the results



Communication Networks

Conclusion



We can view networks in terms of the **OSI layered model**

The **lowest 3 layers** provide the **infrastructure** for transmitting and delivering messages

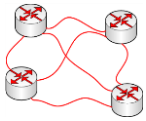
The **higher layers** implement the host-based **application**-specific communication

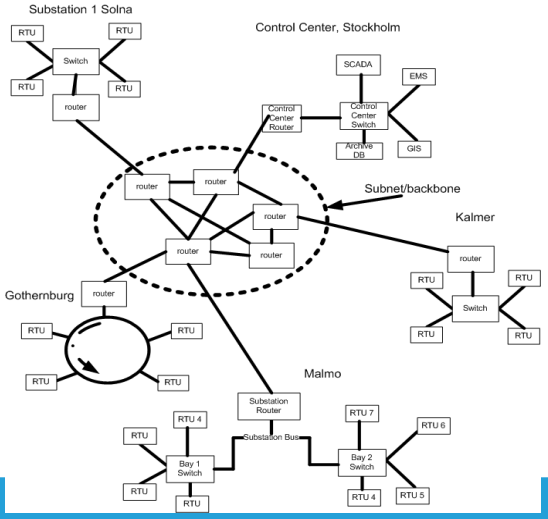
A **combination of protocols** can be used to provides services eg. DNS lookup before sending HTTP GET

Now we can say a lot more about the process and station bus

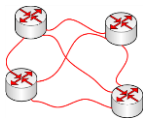
What to expect next…

Topology of a network





What to expect next…



Topology of a network
Media Access Control Techniques
Routing and addressing
Protocols found in SCADA and SAS