KTH ROYAL INSTITUTE
OF TECHNOLOGY

Lecture #12
Communication metrics and Timesync

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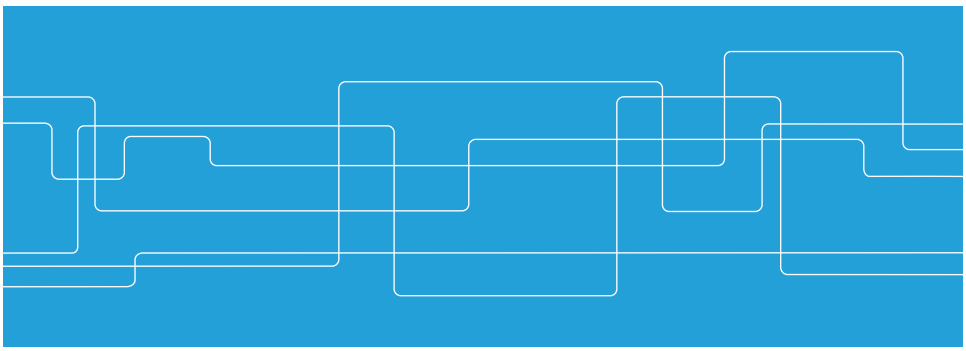


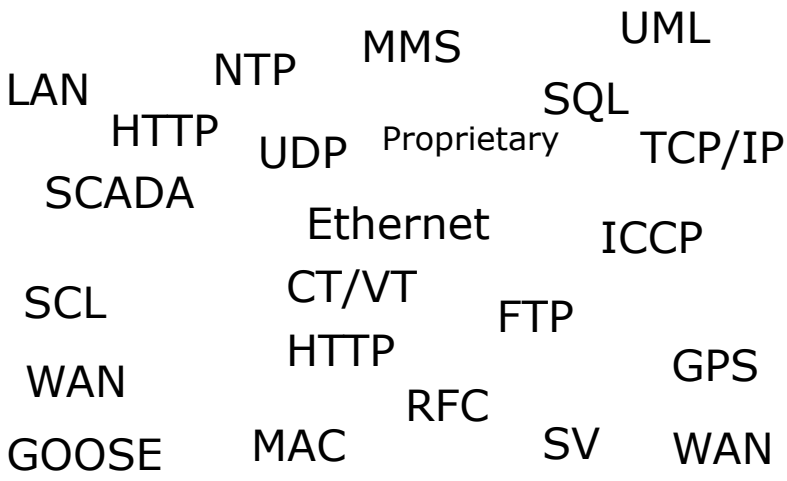
In this series…

- 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…

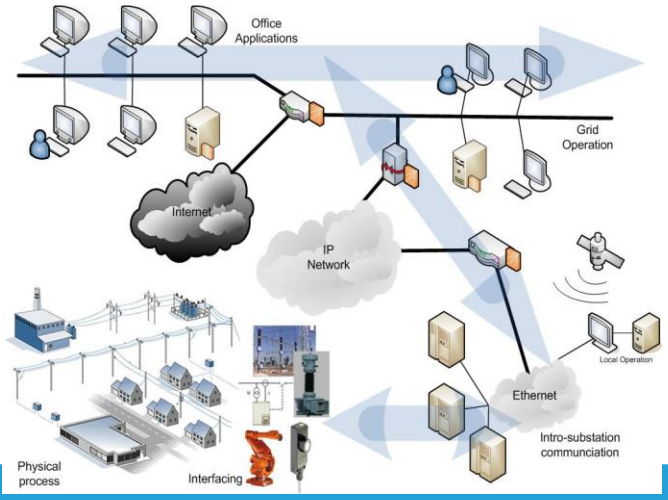
- Lecture #11
  - Power systems communication
  - Wireshark exercises
- Lecture #12
  - Delay, Loss and Throughput
  - Quality-of-Service
  - Time synchronization
  - Project assignment Q&A

Some terms and acronyms…



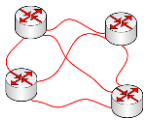
Recap

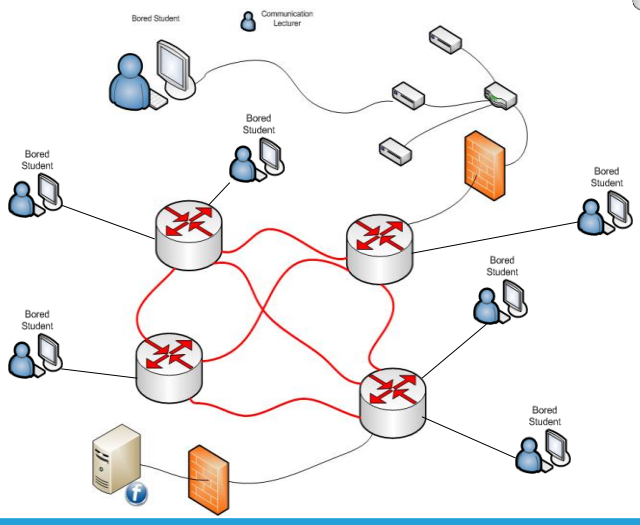
Computers and Networks in Power Systems



Recap

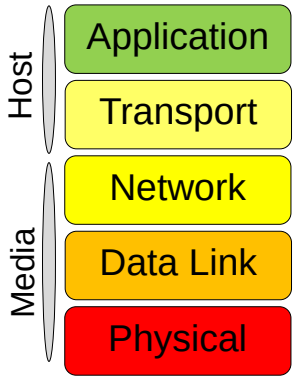
Protocol basics





Recap

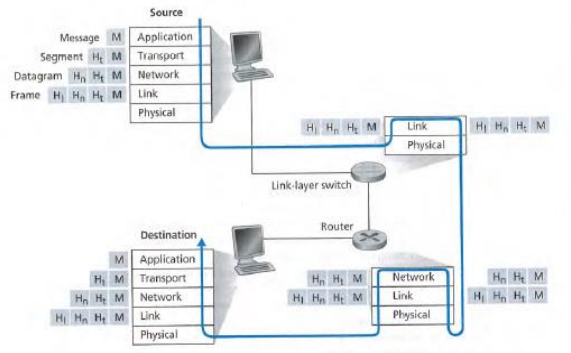
The OSI model



Recap

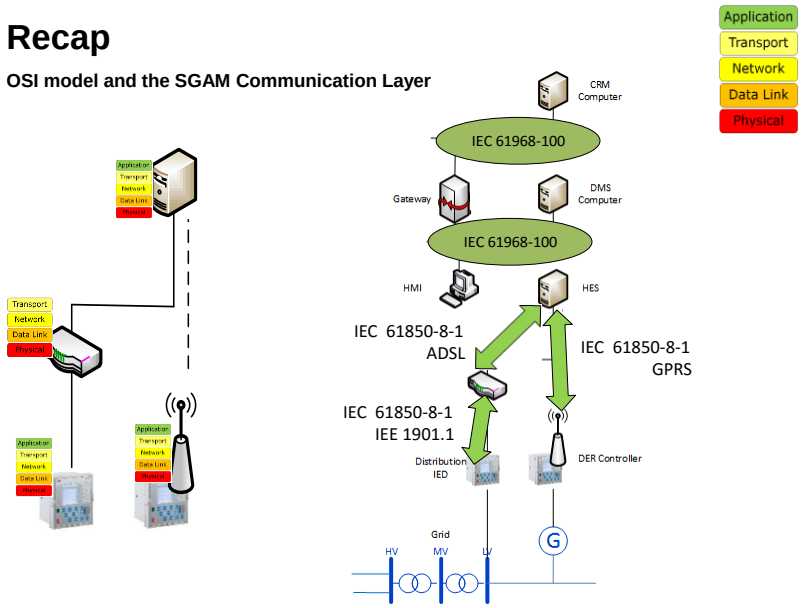
Transition between layers

Application
Transport
Network
Data Link
Physical



Recap

OSI model and the SGAM Communication Layer



Recap

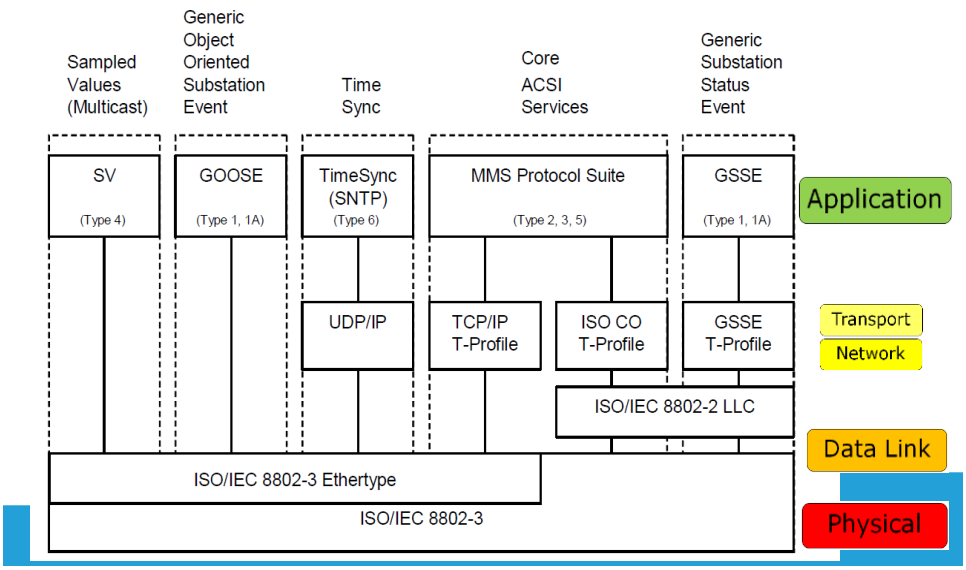
Protocols used in power systems

IEC 61850
- GOOSE
- SV
- MMS

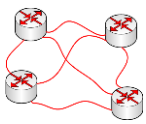
IEC 60870-5-101 and -104
Modbus
DNP3
IEEE C37.118
IEC 61968-100
ICCP

Recap

Protocols used in power systems



Delay, loss and throughput

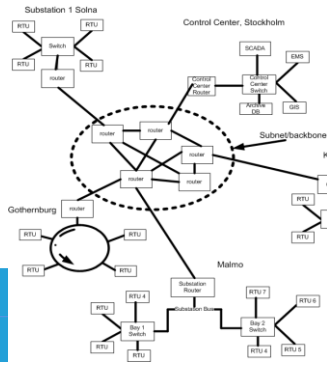


Delay

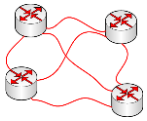
Loss

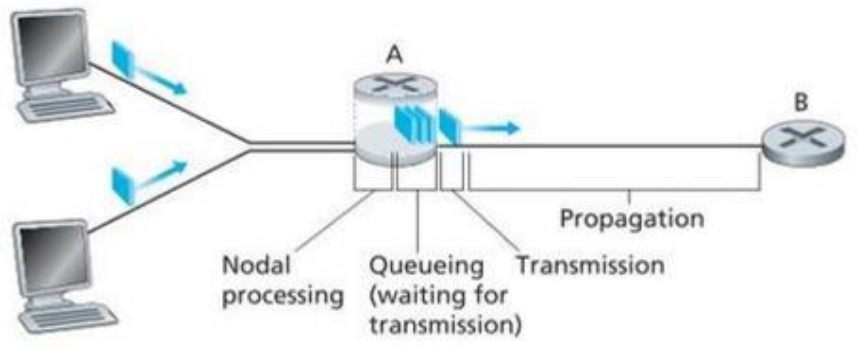
Throughput

We can't just move any amount of data through a network at light speed, there are limitations…



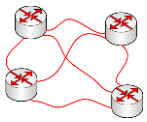
Delay, loss and throughput





From Kurose & Ross 1.4.1

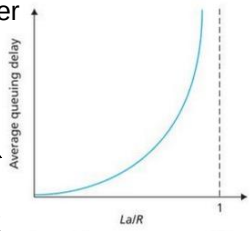
Delay, loss and throughput



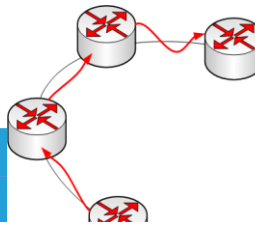
Delay

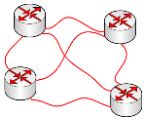
Composed of:

- Processing delay (typically **µs**)
  - Time taken for a router to process packet header
- Queuing delay (**µs** to **ms**)
  - Time that the packet waits in the queue



- Transmission delay (**µs** to **ms**)
  - Time taken to push the packet bits onto the link
  - Dependent on transmission rate of out-link (e.g. 10 Mbps)
- Propagation delay ($2x10^8$ m/s to $3x10^8$ m/s)
  - Time taken for signal to reach it's destination





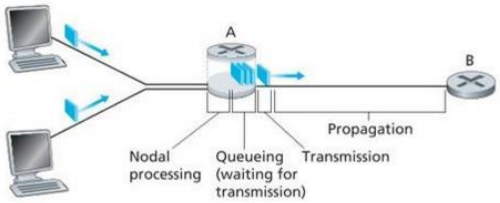
Delay, loss and throughput

Delay

If we let d_{proc}, d_{queue}, d_{trans}, and d_{prop} denote the processing, queuing, transmission, and propagation delays,

then the total nodal delay is given by:

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$



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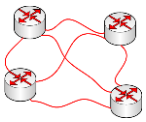


Delay, loss and throughput

Loss

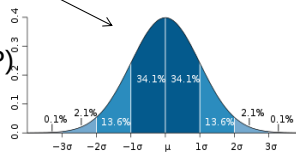
Occurs when packets fail to reach their destination

Router with full queue will drop packets

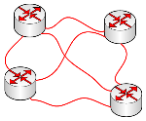
Corruption of packet data on link

- Bad signal-to-noise ratio

Causes undesirable “jitter” in Real-Time applications



Recovery often by higher-layer protocols (ex. TCP)



Delay, loss and throughput

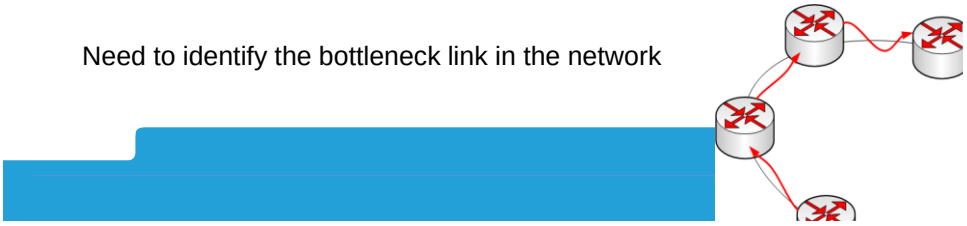
Throughput

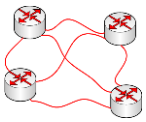
Measured in bits-per-second (bps)
- usually *not* Bytes (8-bits)

Instantaneous
- At any instant in time

Average
- Over a period of time

Need to identify the bottleneck link in the network





Delay, loss and throughput

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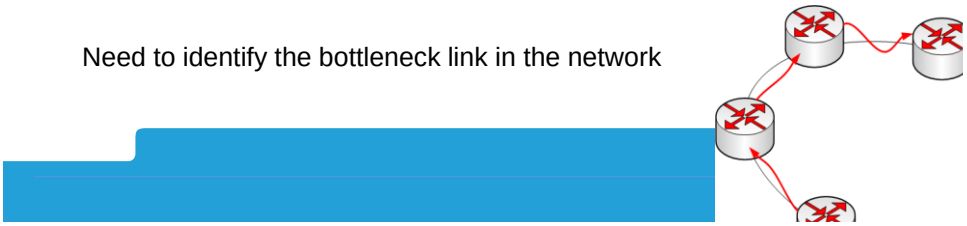
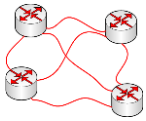


Quality of Service

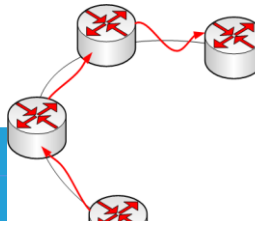
General



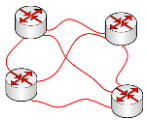
Quantified by:

- Error rates
- Bit rate
- Throughput
- Transmission delay
- Availability
- Jitter

Network congestion causes QoS issues…



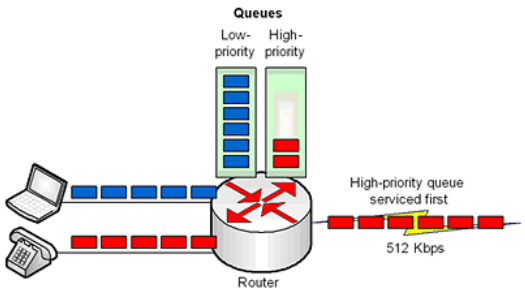
Quality of Service



Resource reservation control mechanisms:

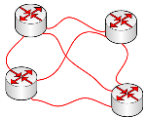
Network DiffServ (DSCP), IntServ (RSVP) in IP header Type-of-Service field

Data Link VLAN IEEE 802.1Q and IEEE 802.1p inserts tag in Ethernet header



Quality of Service

Applications

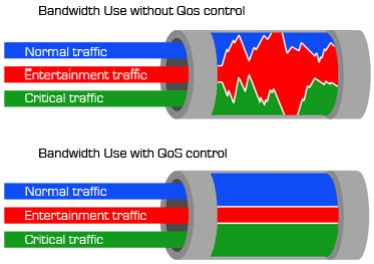


Network-layer QoS methods can be used to prioritise operations traffic over maintenance and data engineering traffic in utility backhaul networks.

VirtualLANs are commonly used in IEC 61850 installations

GOOSE datasets are assigned VLAN IDs

Managed Ethernet switches can set Individual priories for each VLAN



Time Synchronization

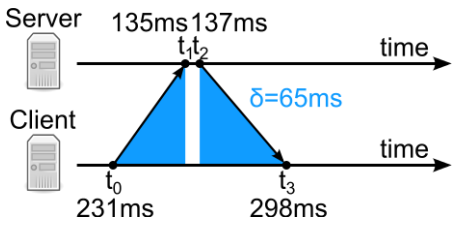
NTP

IEEE 1588 Precision Time Protocol

IRIG-B

Time Synchronization

NTP



Carried over UDP/IP

The round-trip delay δ is computed as:

$$\delta = (t_3 - t_0) - (t_2 - t_1)$$

where

t_0 is the client's timestamp of the request packet transmission,

t_1 is the server's timestamp of the request packet reception,

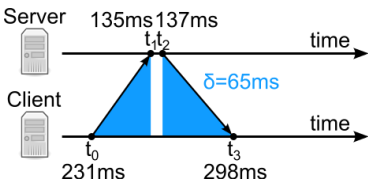
t_2 is the server's timestamp of the response packet transmission and

t_3 is the client's timestamp of the response packet reception.

Then the offset $\theta = \frac{(t_1 - t_0) + (t_2 - t_3)}{2}$ is minimised by adjusting the clock frequency.

Time Synchronization

NTP



Accurate to

- within ca. 10ms on the Internet
- About 1ms on a LAN

Sensitive to traffic congestion

Simple NTP (SNTP) is a stateless version of NTP for embedded devices

Windows query:

```
> w32tm /stripchart /computer:ntp.kth.se
```

shows θ and δ values for each query

OSX NTP test: `>/usr/sbin/ntpdate -d ntp.kth.se`

Time Synchronization

NTP clock strata

Stratum 0: Atomic clocks/GPS

Stratum 1: ms synch servers

Stratum 2 – etc.

.
.
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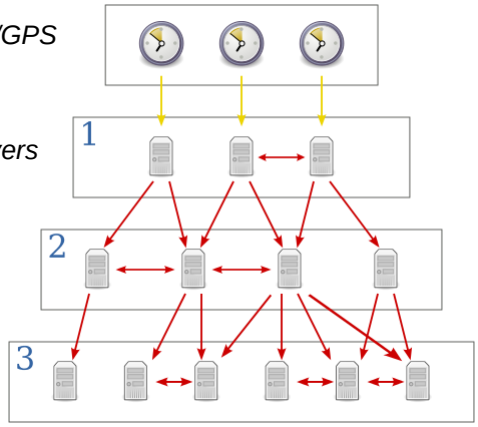


Time Synchronization

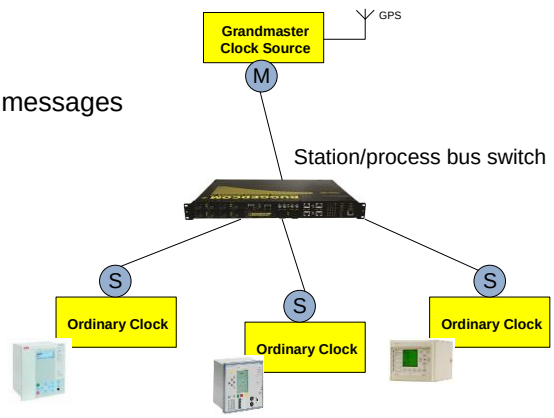
IEEE 1588 (Precision Time Protocol)

Also carried over UDP/IP

IP multicast used to distribute messages

Two steps in process:

- Best Master Clock election
- Synchronization



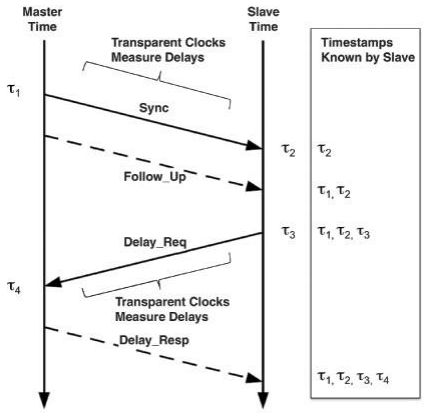
Time Synchronization

IEEE 1588 (Precision Time Protocol)

Message types:

- Sync
- Delay_Req
- Follow_up
- Delay_Resp

- Announce
- Management
- Signalling



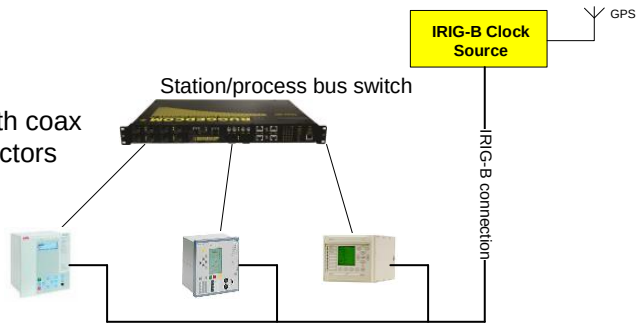
Time Synchronization

IRIG-B

Military/industrial time code standard from 1960

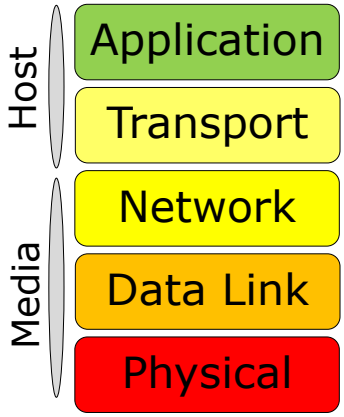
Still very common!

Uses own wiring bus with coax cabling and BNC connectors



Conclusions

Thinking of getting a tattoo?



The OSI model will always be fashionable!

Conclusions

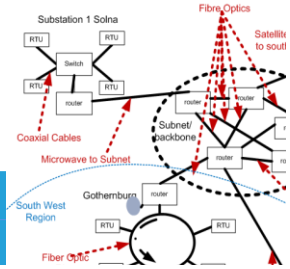
A language to categorise and understand the many protocols, media and devices that exits

- The OSI model

Looked at the architectures, protocols and network infrastructure used in power systems control (SCADA & SAS)

Routing and switching in more detail

Protocols used in power systems applications



Project assignment Q&A

Workflow

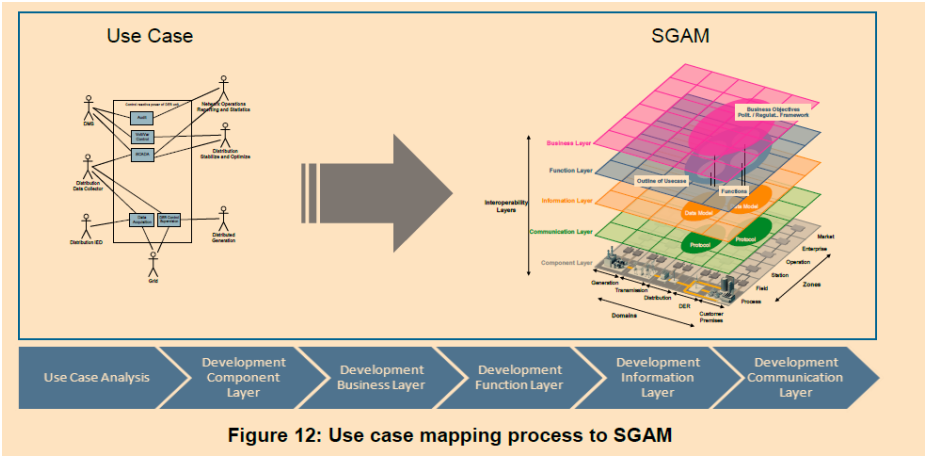


Figure 12: Use case mapping process to SGAM