Realistic communications emulation for real-time power system simulation

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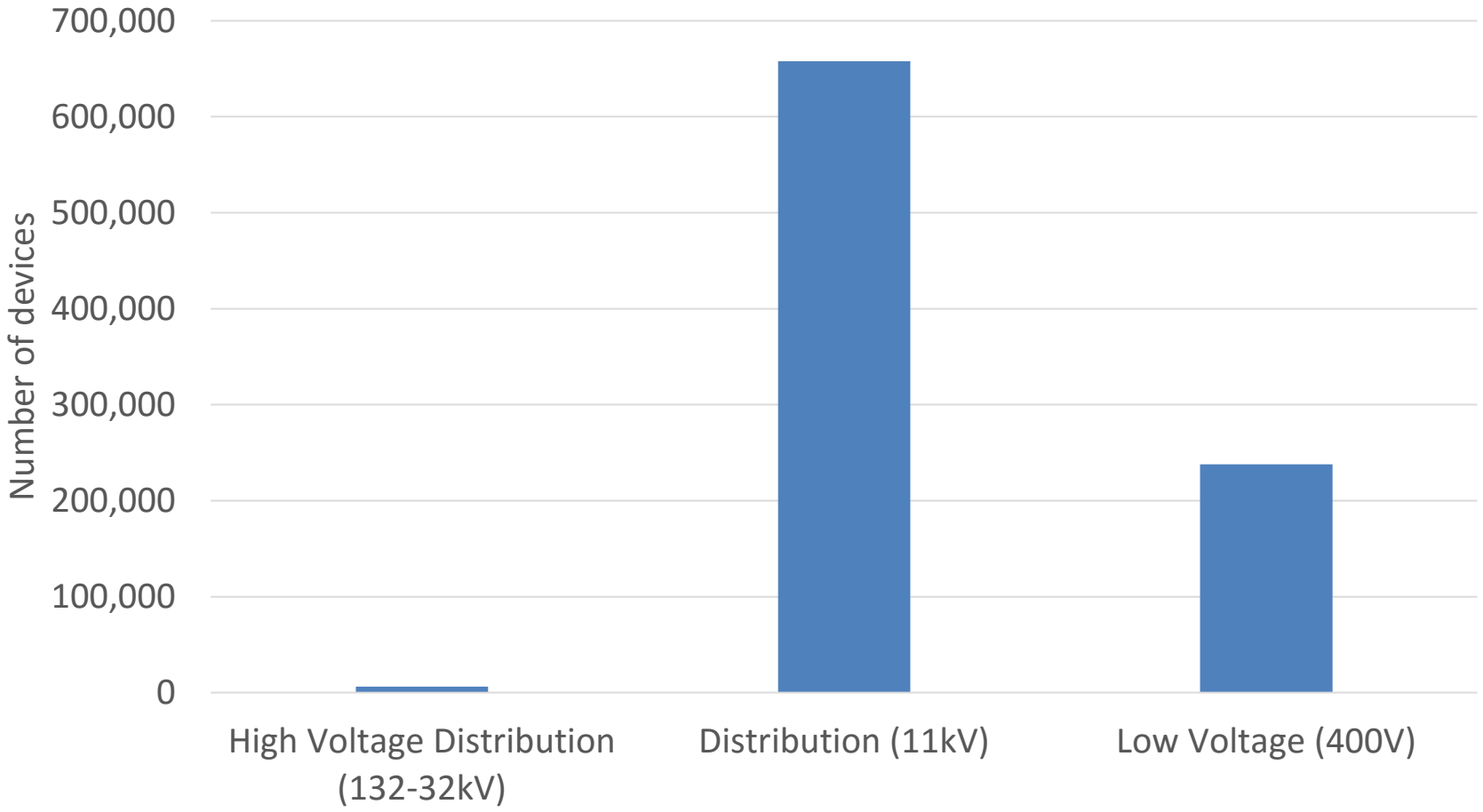
Change in power system

- A large amount of wind and PV generation is being deployed
- Demand side management is enabling highly distributed control methods
- New types of energy entities are emerging in the smart grid: smart cities, demand side aggregators, community energy schemes, etc.

Problems

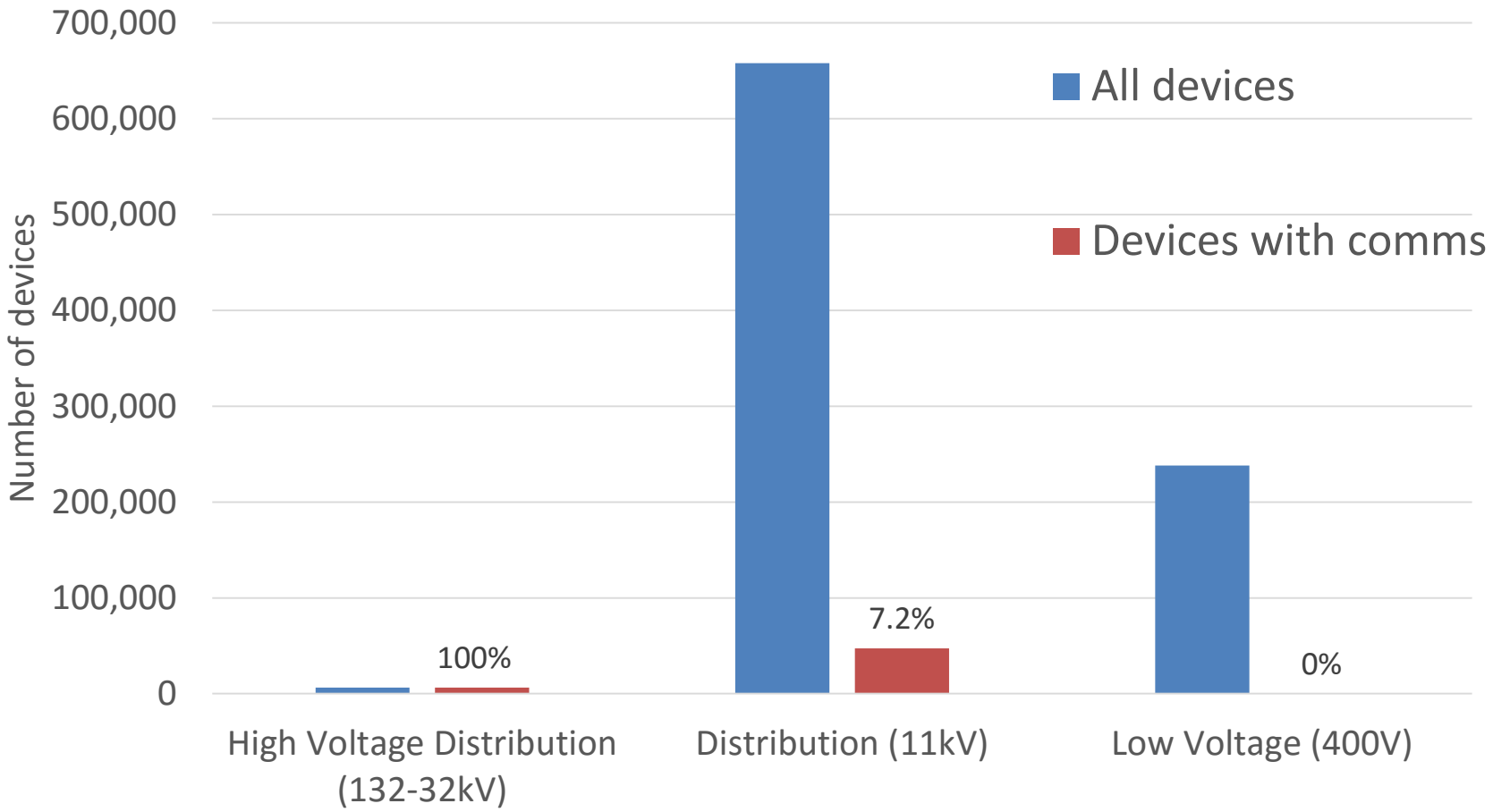
- Observability
  - To ensure the flexibility of the changing yet uncertain requirements for the power grid
- Control
  - Need to actively manage the power network, generation, storage and demand
  - To maintain stability and reliability

Communications capable assets in different domains of the UK power grid



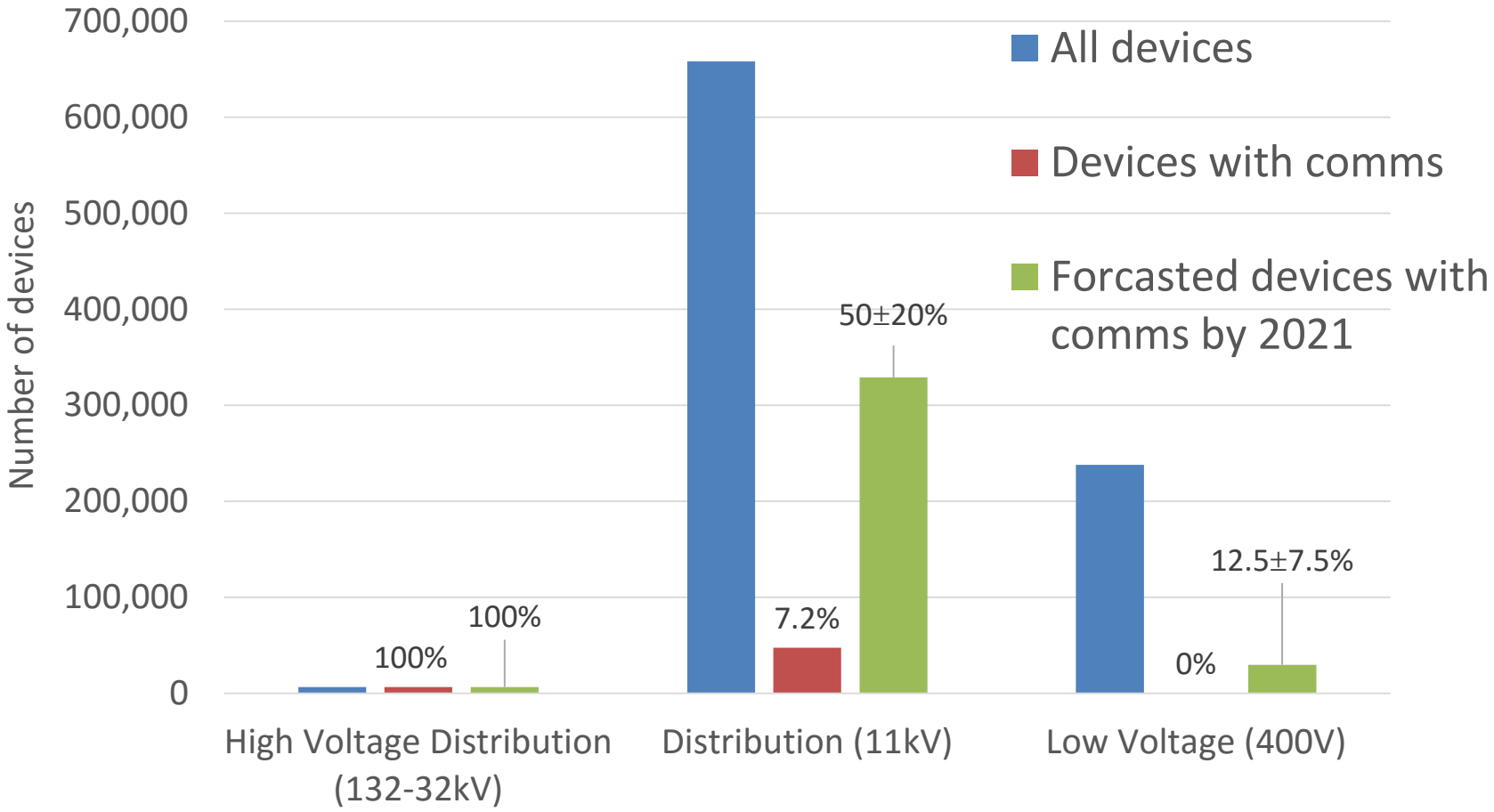
[1] A. Hulme, V. Sennes, "DNO - SMART GRID COMMUNICATIONS REQUIREMENTS", Energy Networks Association, 20th Dec 2011. [Online] Available: http://www.energynetworks.org/assets/files/electricity/engineering/telecoms/eitc/restricted/Reference%20Doc/Telent.pdf

Assets equipped with communications

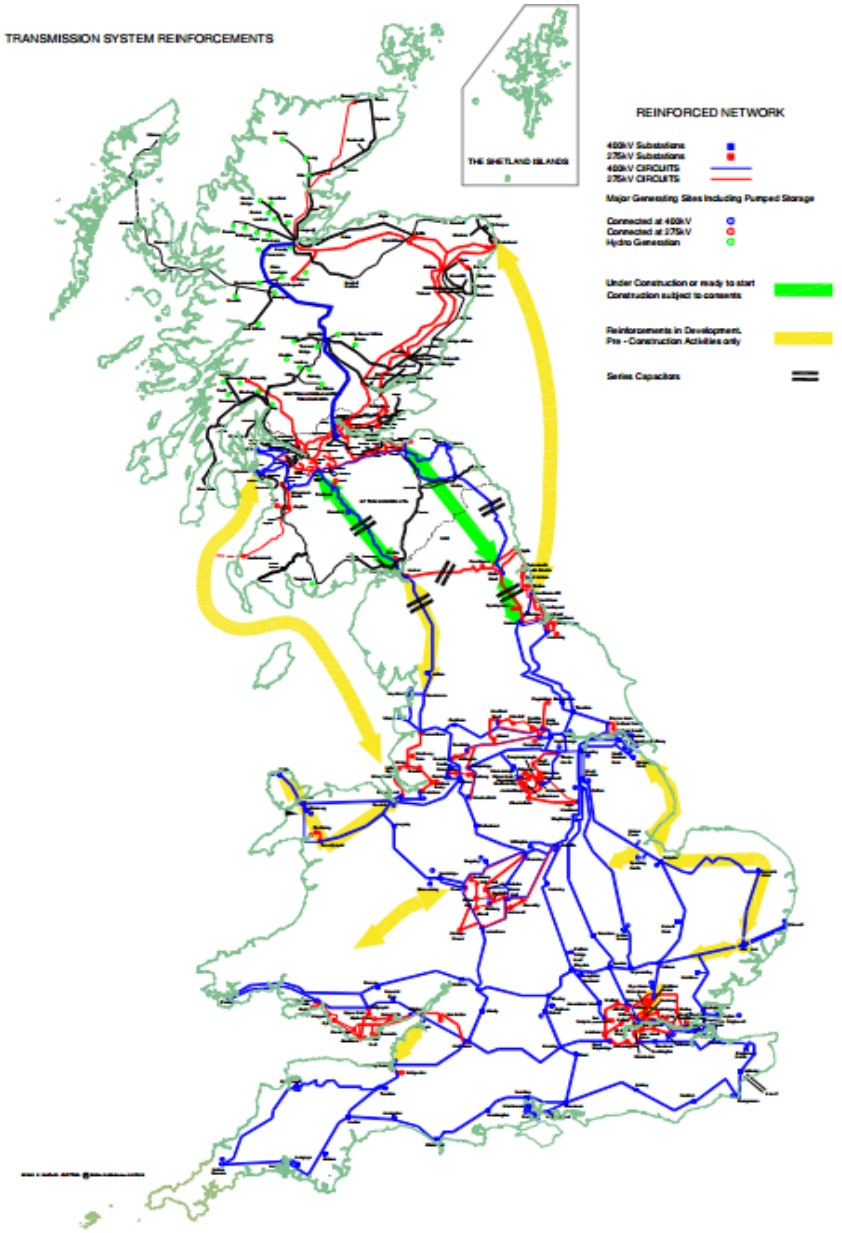


[1] A. Hulme, V. Sennes, "DNO - SMART GRID COMMUNICATIONS REQUIREMENTS", Energy Networks Association, 20th Dec 2011. [Online] Available: http://www.energynetworks.org/assets/files/electricity/engineering/telecoms/eitc/restricted/Reference%20Doc/Telent.pdf

Forecasted assets equipped with communications



[1] A. Hulme, V. Sennes, "DNO - SMART GRID COMMUNICATIONS REQUIREMENTS", Energy Networks Association, 20th Dec 2011. [Online] Available: http://www.energynetworks.org/assets/files/electricity/engineering/telecoms/eitc/restricted/Reference%20Doc/Telent.pdf



Type	Qty per 2km sq
Metropolitan	150+
Inner Urban	101-150
Urban	41-100
Outer Urban	11-40
Rural	1-10

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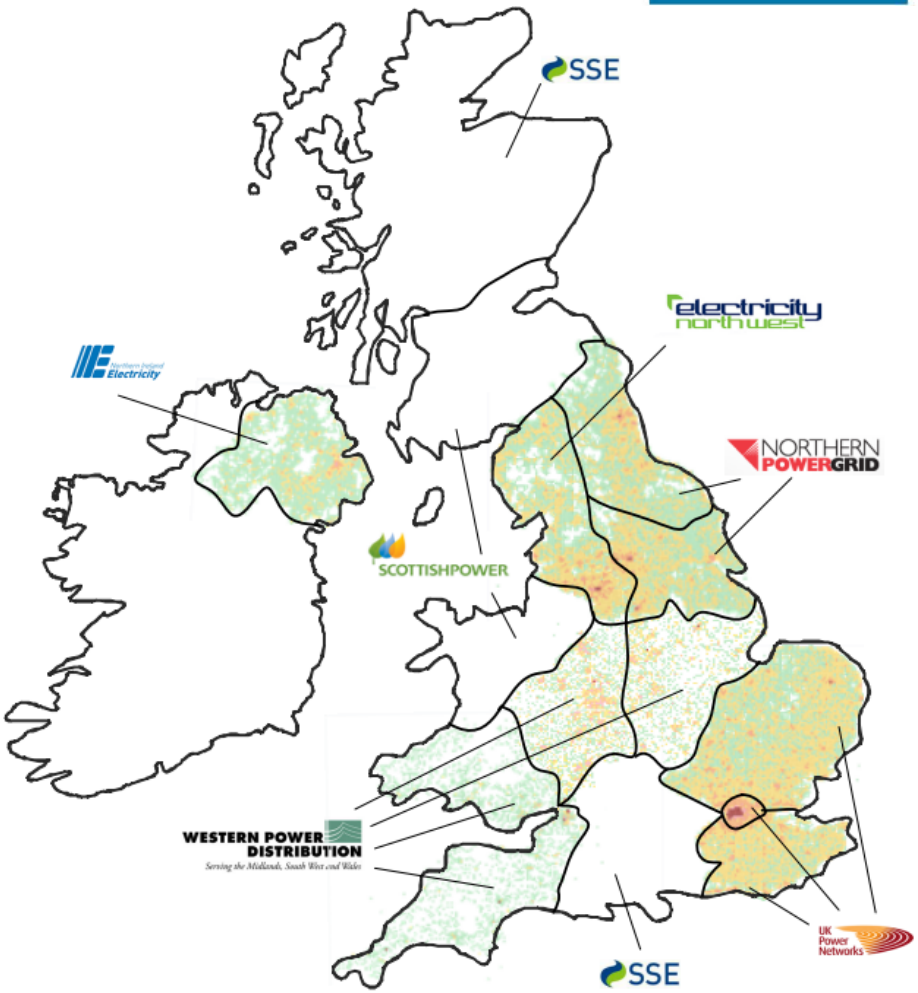


[2] ENSG, "Our Electricity Transmission Network: A Vision for 2020", July 2009. [Online] Available: http://webarchive.nationalarchives.gov.uk/20100919181607/http://www.ensg.gov.uk/assets/ensg_transmission_pwg_full_report_final_issue_1.pdf

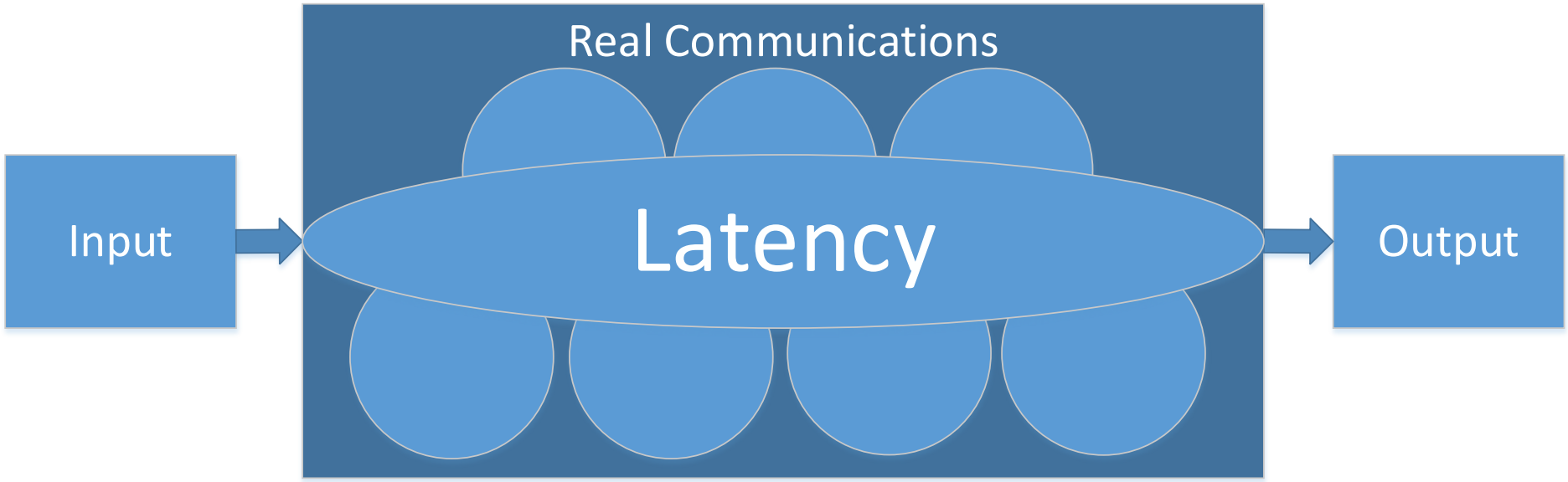
[1] A. Hulme, V. Sennes, "DNO - SMART GRID COMMUNICATIONS REQUIREMENTS", Energy Networks Association, 20th Dec 2011. [Online] Available: http://www.energynetworks.org/assets/files/electricity/engineering/telecoms/eitc/restricted/Reference%20Doc/Telent.pdf

Technologies

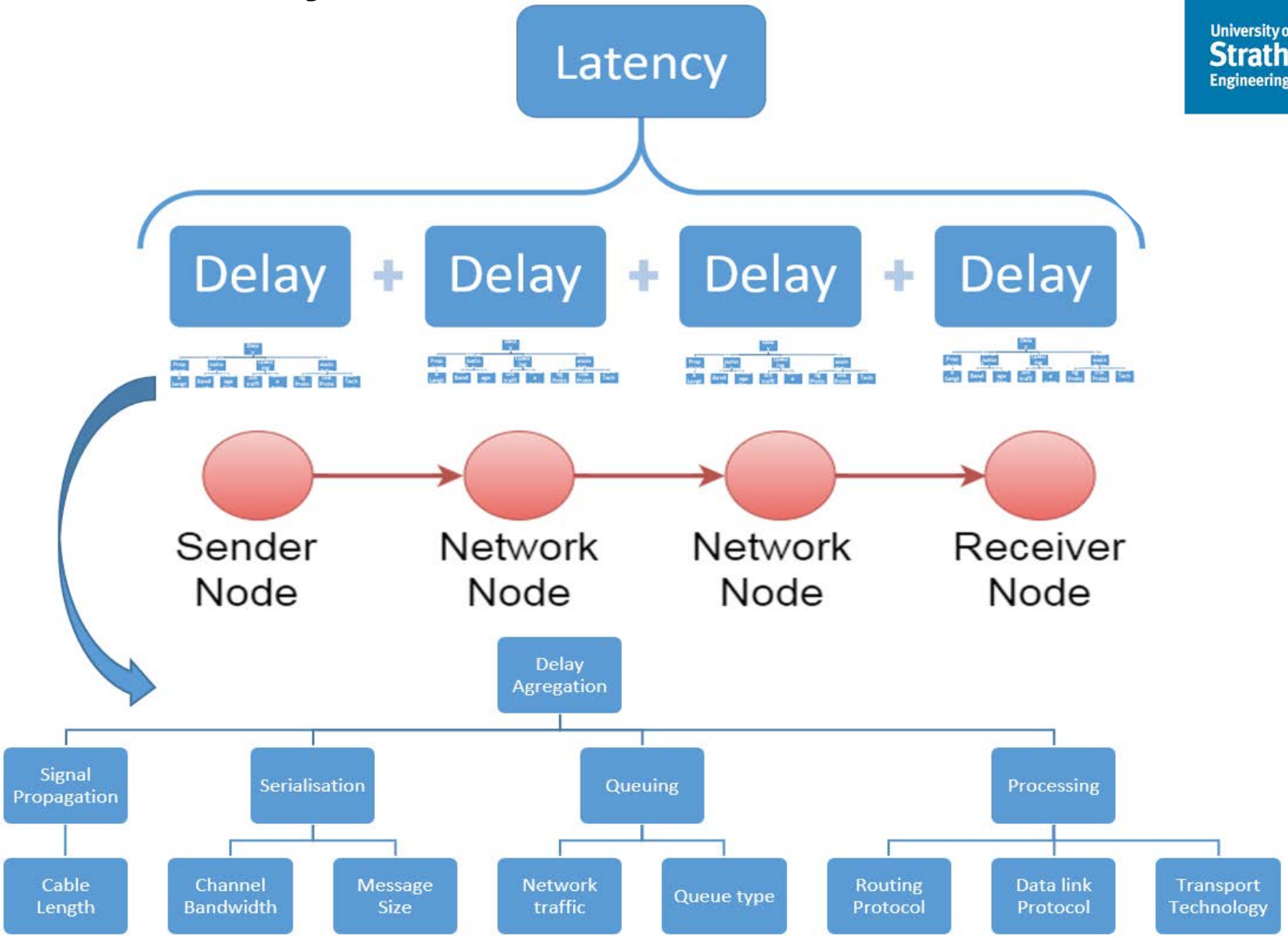
	Home Area Network (HAN)	Field Area Network (FAN)	Wide Area Network (WAN)
Wired technologies	• Ethernet • High data-rate PLC (multimedia, electric vehicle) • Low data-rate PLC (home automation, electric vehicle) • Copper pair	• **Low data-rate PLC** (Lonworks G1,G3, ...) • Fiber (FTTH) • DSL • TV Cable • Phone network	• PLC • Fiber • DSL
Wireless technologies	• Wifi • Home automation standards (ZigBee, Z-Wave...) • Energy & metering standards (M-Bus, KNX..) • DECT	• RF Point to Point • **RF Mesh** • **Callular** (GPRS, 3G, 4G/LTE) • Wifi • WiMax • Satellite	• Cellular (GPRS, 3G, 4G/LTE • WiMax • Satellite

[3] BearingPoint, Figure:' Main technologies used into smart-grid project', Sep 2013. [Online] Available: http://energypoint.bearingpoint.com/europe/2013/09/05/which-communications-technologies-for-ami-projects/

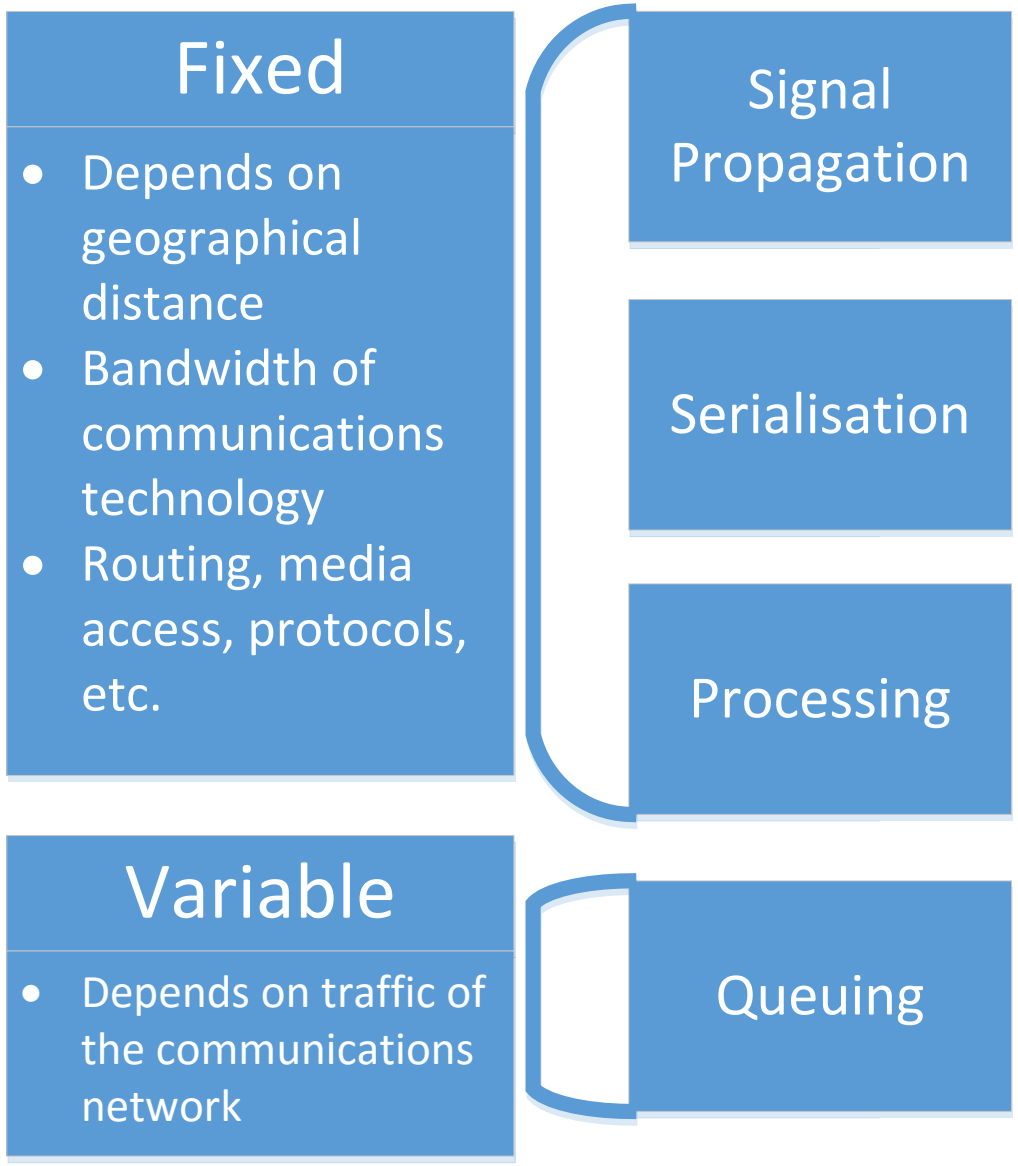
Communications



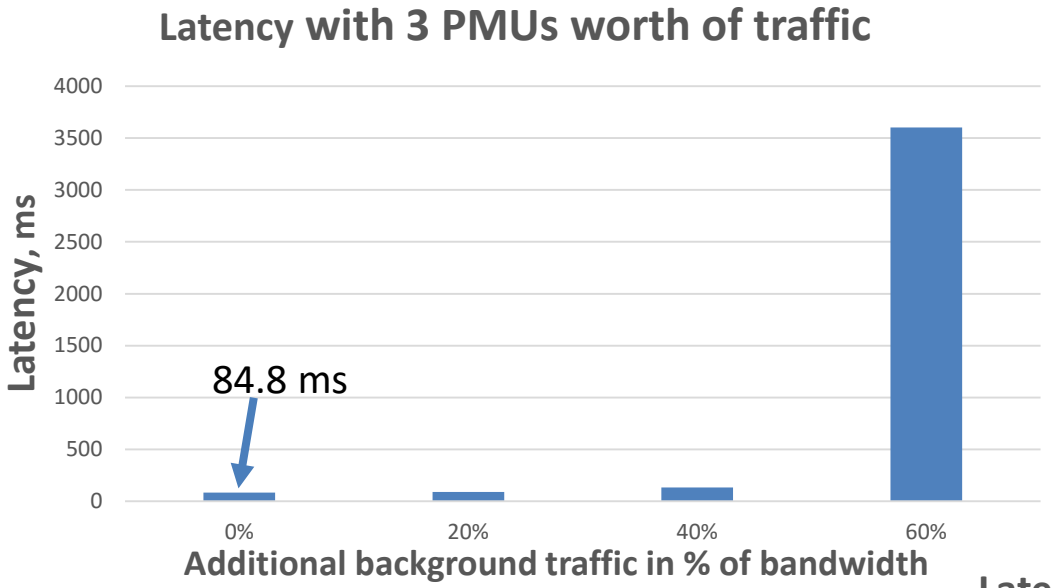
Latency

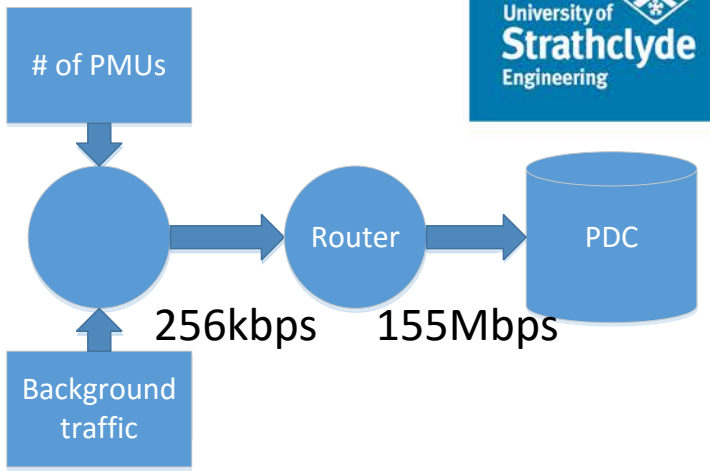

Latency
Delay
+
Delay
+
Delay
+
Delay
Sender Node
Network Node
Network Node
Receiver Node
Delay Agregation
Signal Propagation
Serialisation
Queuing
Processing
Cable Length
Channel Bandwidth
Message Size
Network traffic
Queue type
Routing Protocol
Data link Protocol
Transport Technology

Delay sources



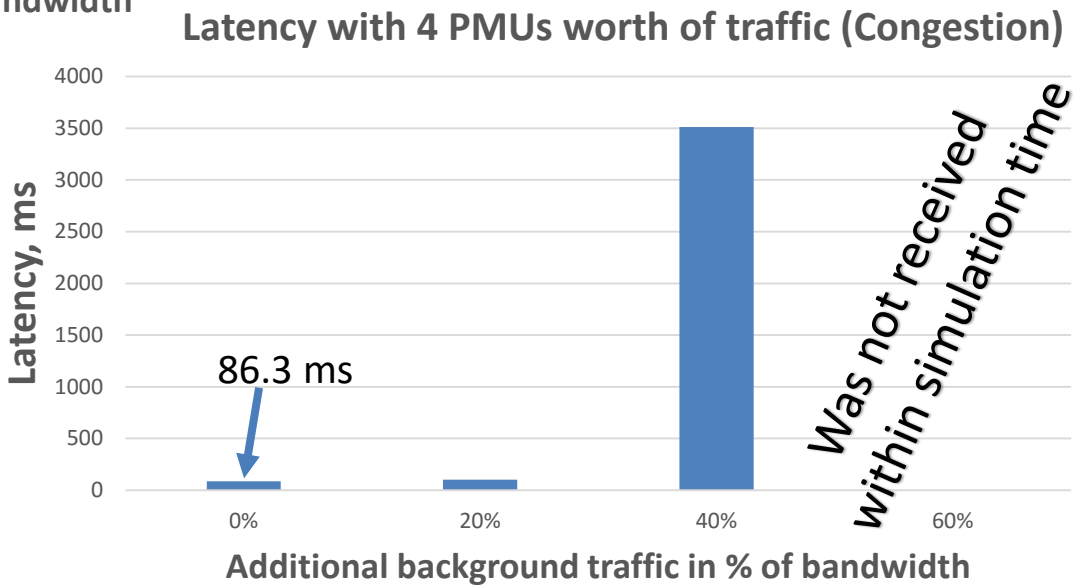
Latency based on variable sources





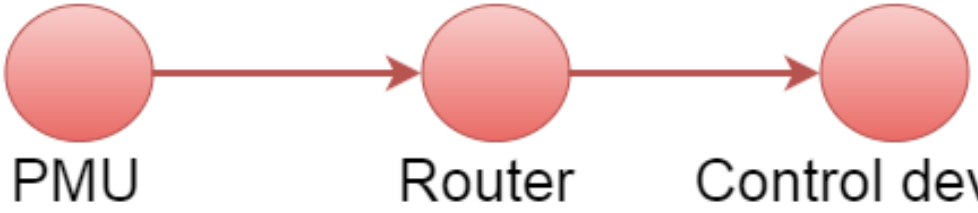
PMU traffic:

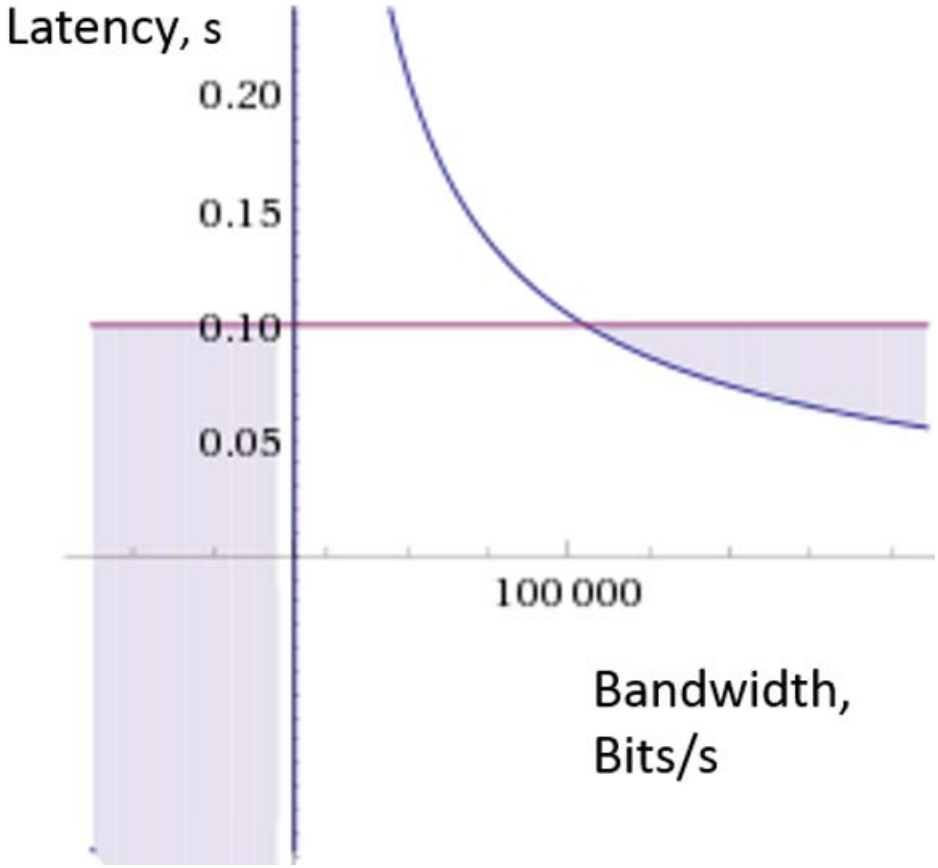
- 50 bytes per message
- 50 messages per second



[6] Golshani Mohammad, Taylor GA, Pisica, I, "Novel performance evaluation of information and communication technologies to enable wide area monitoring systems for enhanced transmission network operation", [Online] Available: http://bura.brunel.ac.uk/handle/2438/11918

Latency based on fixed sources





Varying Bandwidth

No background traffic

Signal Propagation

Serialisation

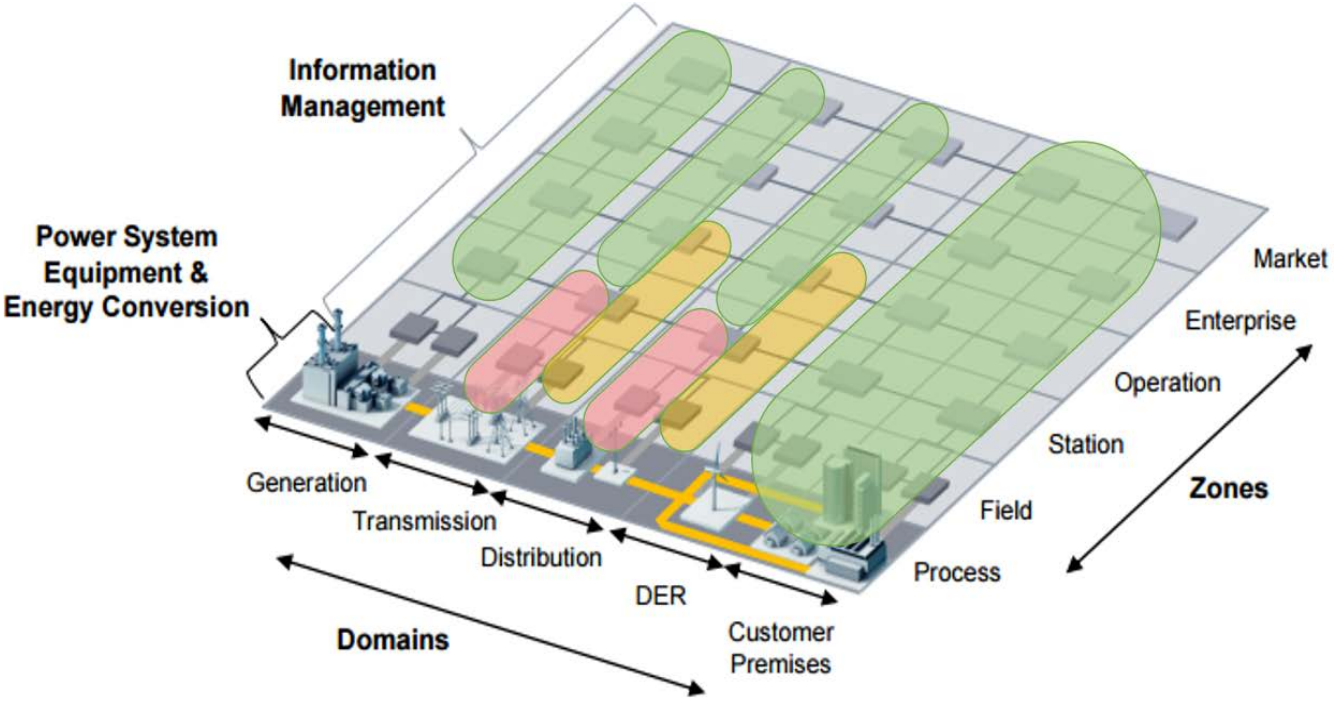
Processing

Queuing

Smart grid application requirements

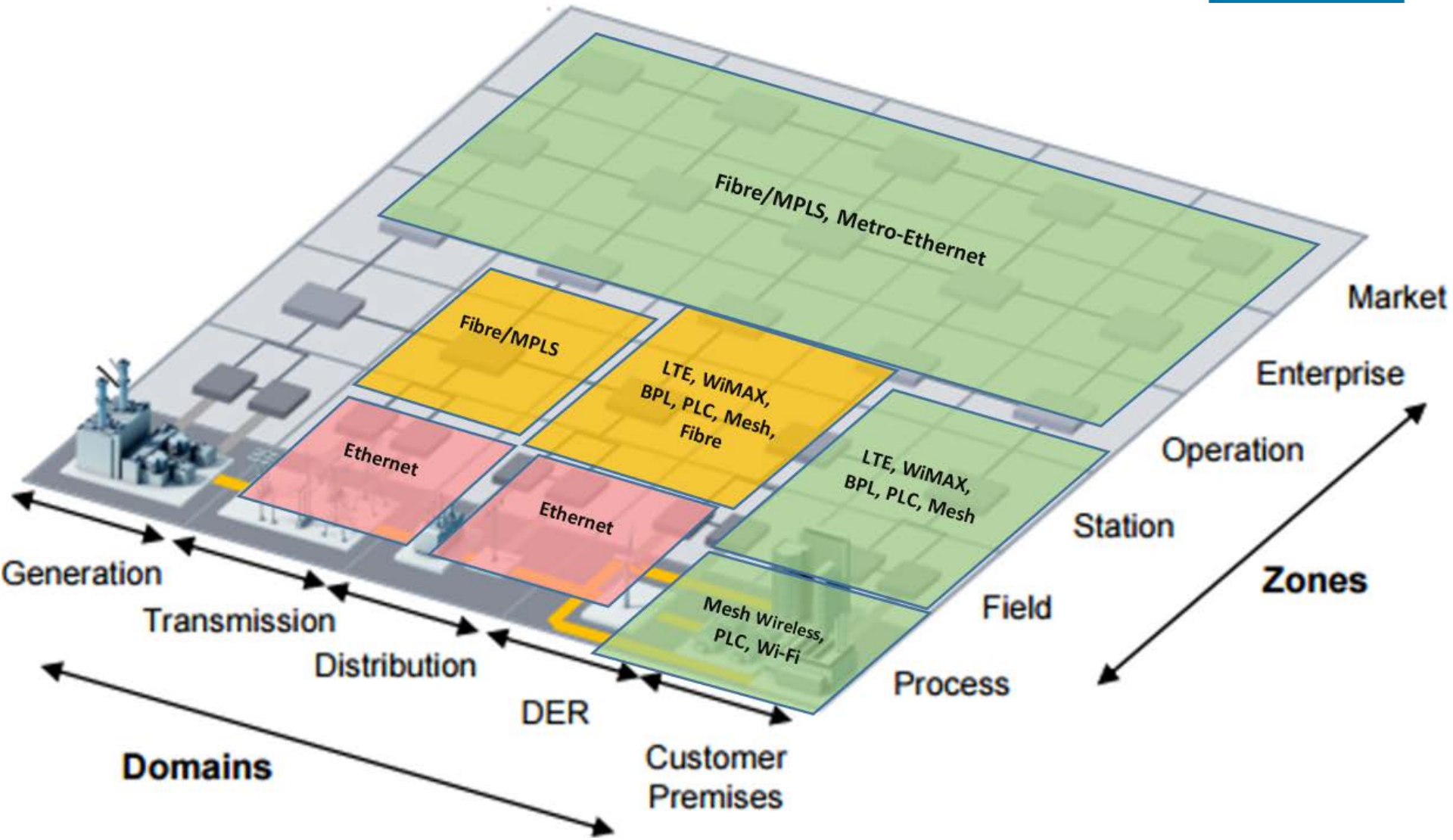
Application	Latency requirements (ms)			Technology
Substation Automation	15-200	<200	Time critical applications	Ethernet, SONET/SDH, MPLS, WiMAX, WiFi, LTE,
Distribution Automation	20-200			
Wide Area Monitoring Systems	200			
Overhead Transmission Line Monitoring	15-200			
Outage Management	2000	<2000	Time sensitive applications	Ethernet, SONET/SDH, MPLS, WiMAX, WiFi, ZigBee, LTE, UMTS
Distribution Management	100-2000			
Home Energy Management	300-2000			
Asset Management	2000			
Meter Data Management	2000			
Advanced Metering Infrastructure	2000			
Distributed Energy Resources and Storage	300-2000			
Demand Response Management	500-5min	<300000(5min)	Latency tolerant applications	Any
Electric Vehicles	2000-5min			

Application and requirements map

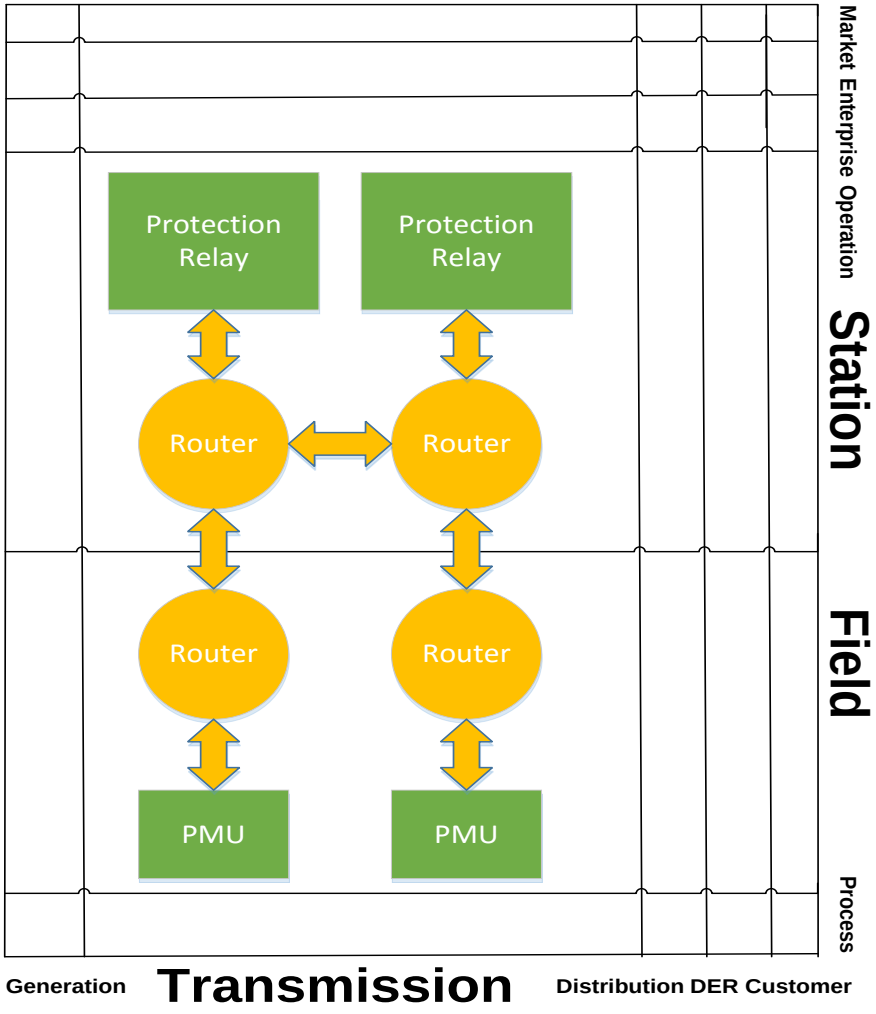


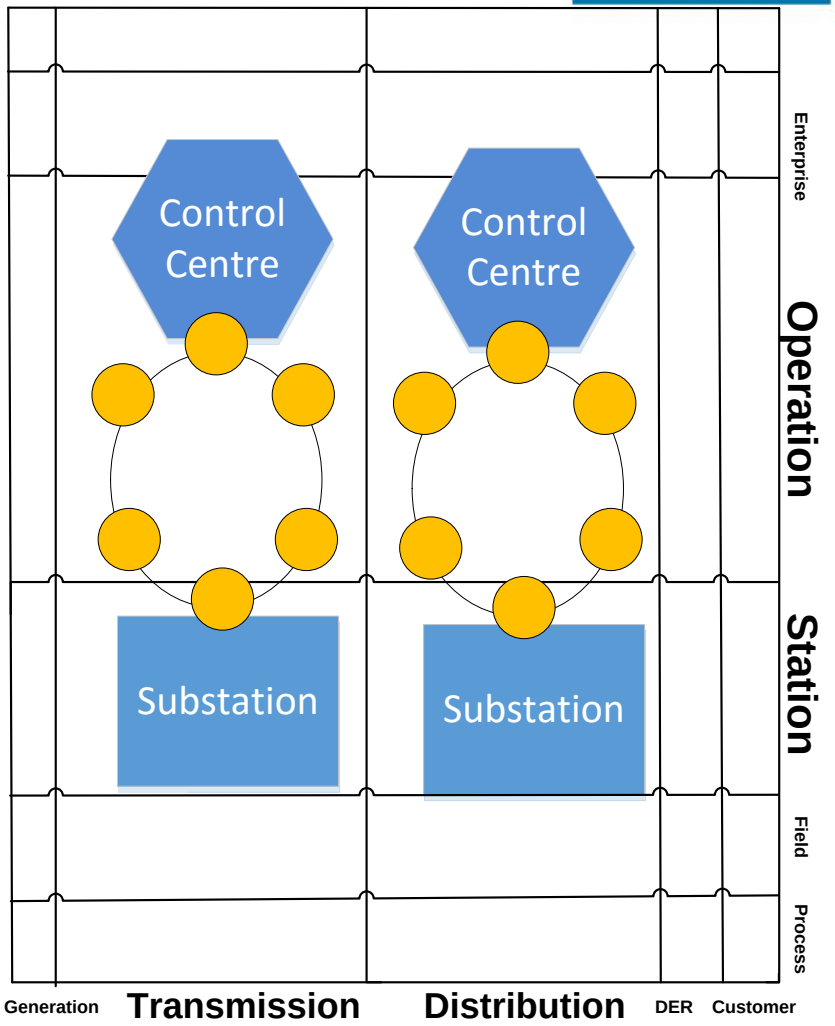
	Latency \ Domain	Generation	Transmission	Distribution	Distributed energy resources	Customer Premises
LAN	6ms		**Protection**			
LAN	30ms			**Protection**		
LAN/ WAN	100ms		**Real-time sensing and actuating**			
LAN/ WAN	100ms		**Substation automation**			
LAN/ WAN	100ms		**Transmission automation**			
WAN	100ms	**Active Generation management**		**Distribution automation**	**Demand side management**	
WAN	1s	**Active Generation management**	**Active network management**	**Distribution automation**	**Demand side management**	
WAN	10s	**Active Generation management**	**Active network management**		**Demand side management**	
WAN	1min+	**Non-real-time measurements for diagnostics, telemetry, asset management**				

Technology map

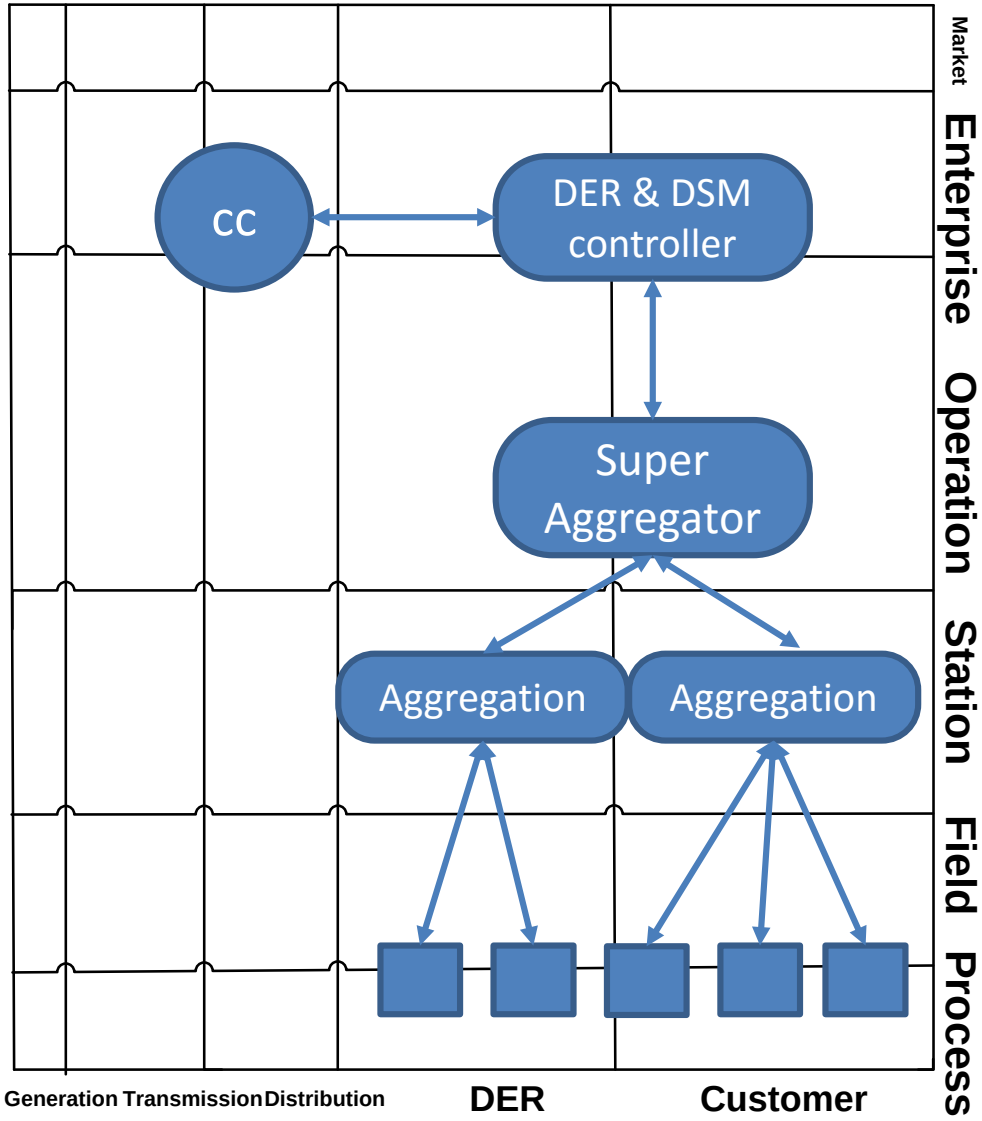


Modelling for use cases with high performance communications

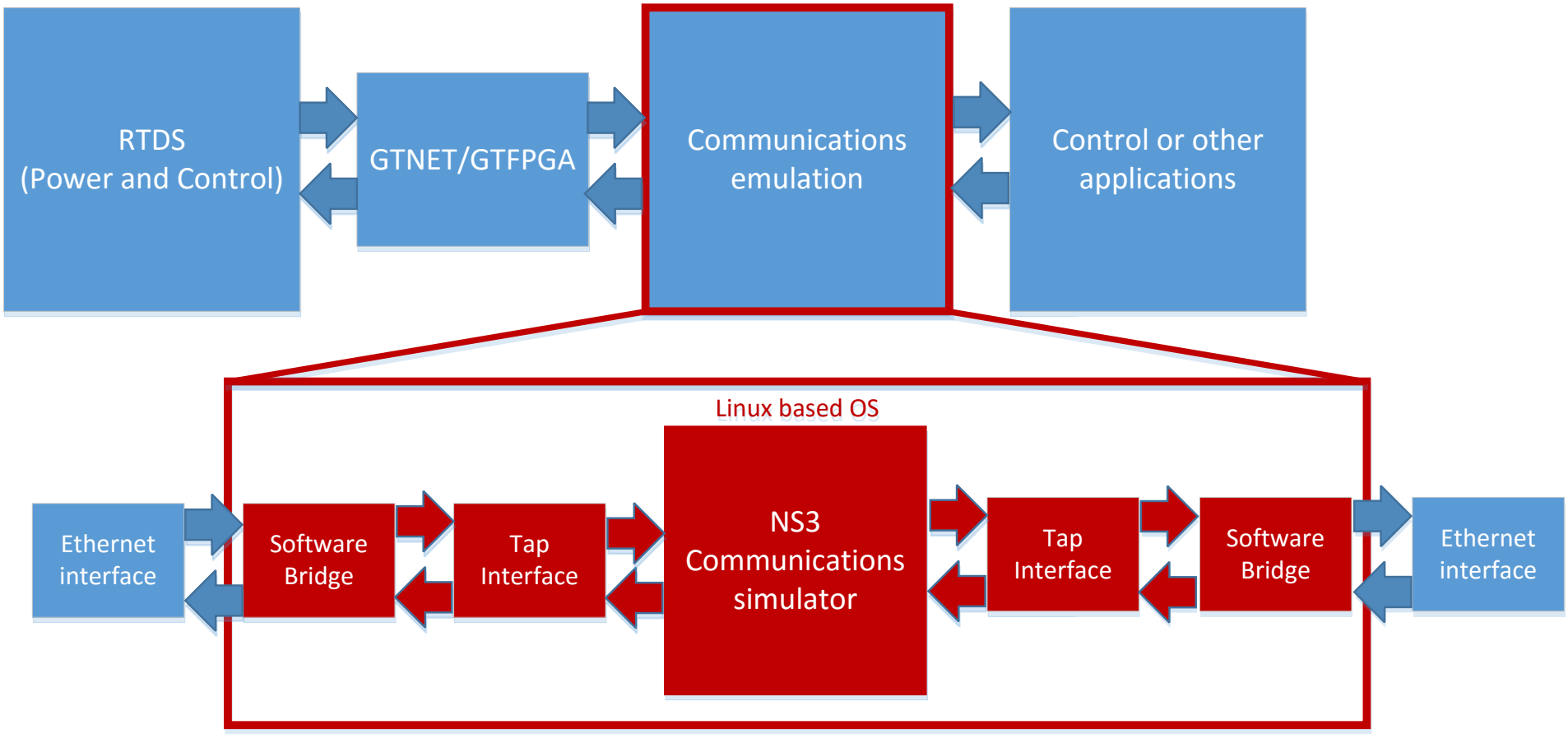




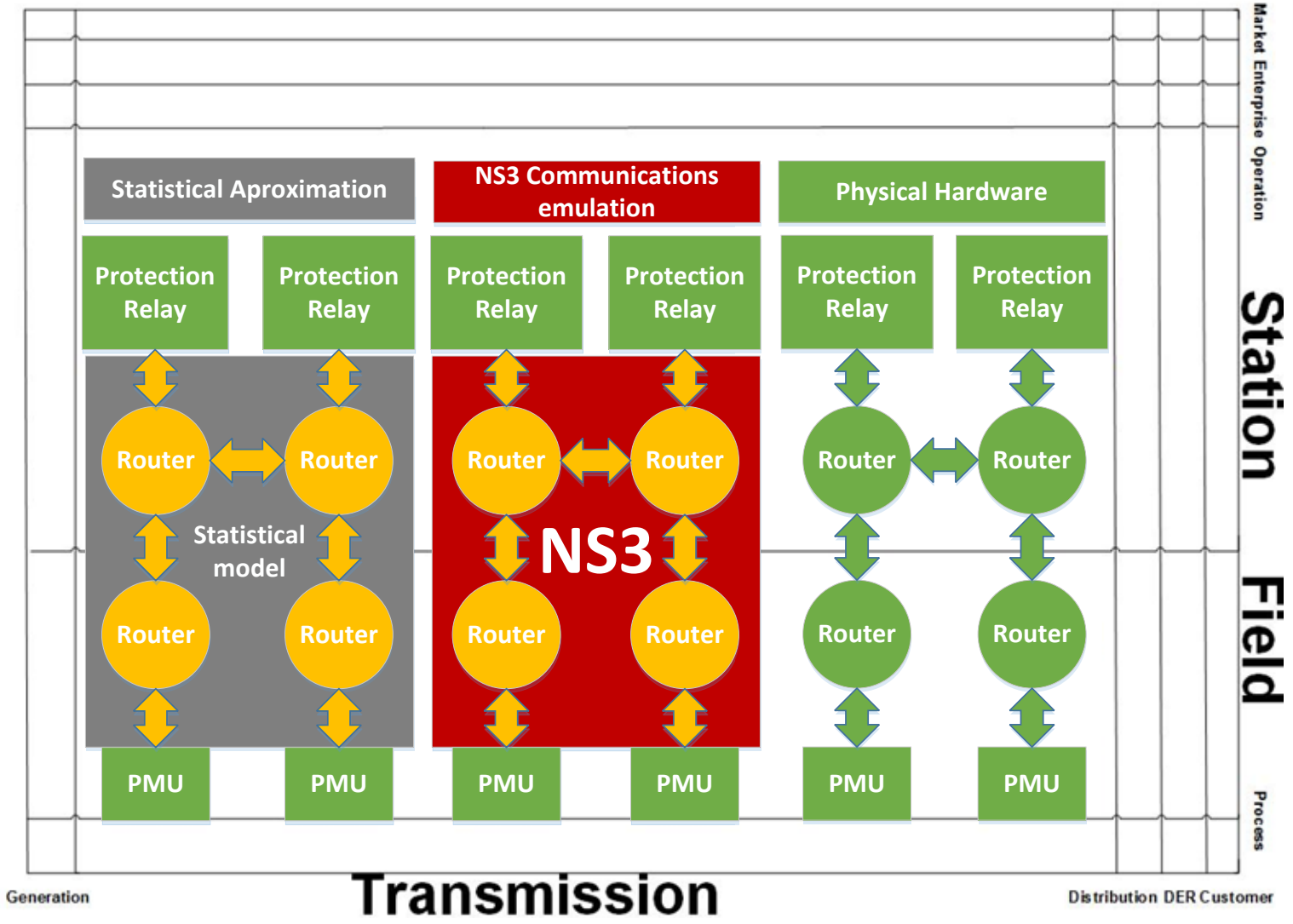
Modelling for use cases with low performance communications



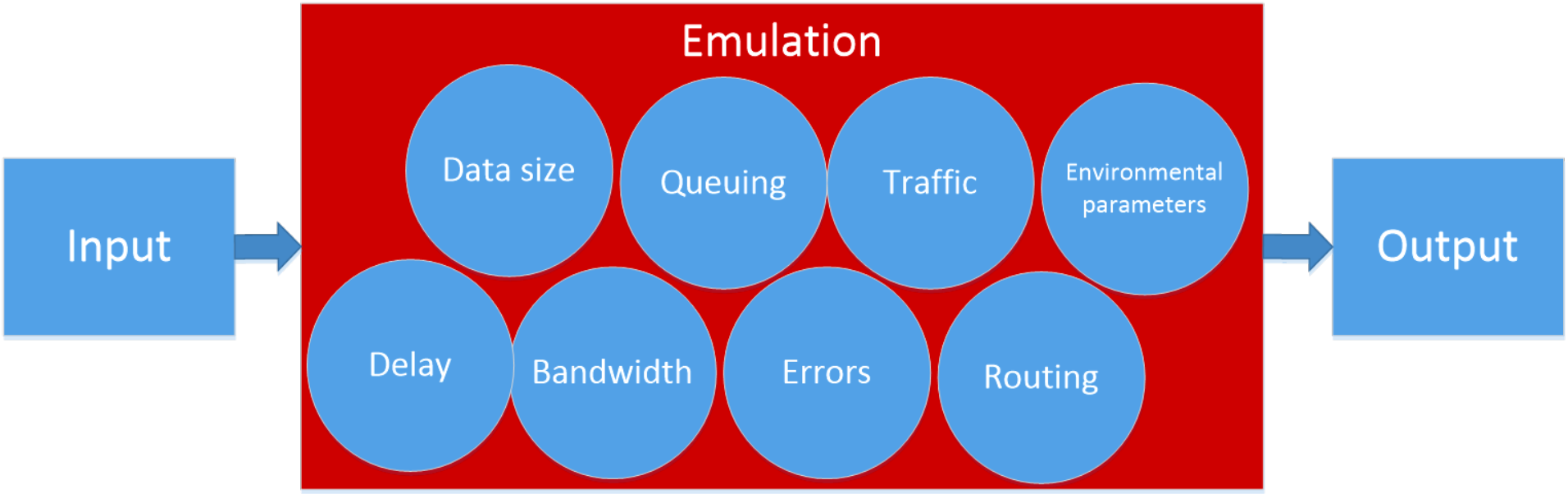
Real-time co-simulation



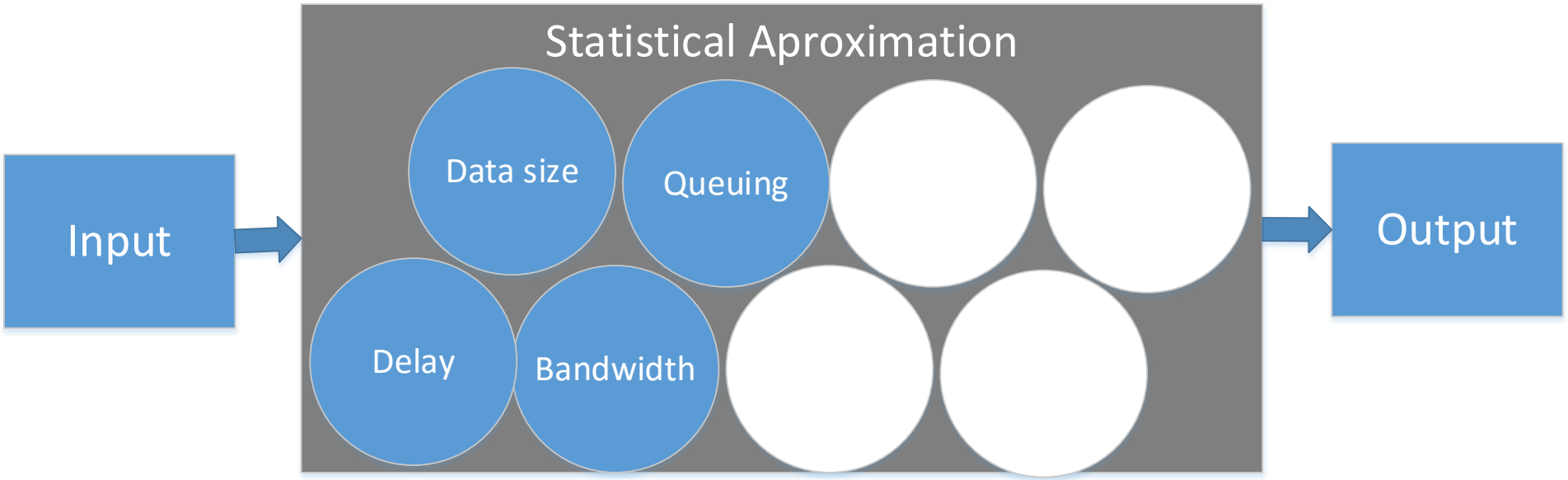
Protection application



Communications emulation



Validated statistic model



Conclusions

- Integration of new resources and applications will depend highly on communications
- It is necessary to accurately represent the increasingly complex communications networks
- Modelling and emulation of communications will enable more realistic real-time grid simulation

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