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An Overview of the upcoming Communications Systems Primer:

A Systems Engineer's Guide to Communications Networks: Modeling Networks as Systems

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Thomas Manley
Canberra, Australia
(Decision Analysis Services, Co-Chair INCOSE Telecomm WG)

Keith Rothschild
Atlanta, Georgia USA
(Cox Communications)

Susan Ronning
Portland, Oregon
(ADCOMM Engineering, Co-Chair INCOSE Telecomm WG)

William Scheible
Mineral, Virginia USA
(MITRE Corp)

INCOSE Telecommunications WG Members

Background

SESA Telecommunications Working Group established

2018

2019

INCOSE Telecommunications Working Group established

Defining Critical Communications Networks: Modelling Networks as Systems published in INCOSE's INSIGHT magazine

2020

Criticality Framework

2021

A Criticality Framework for Resilient Communications Networks (unpublished)

Development and publication of a Telecommunications Primer

2022-23

Telecommunications Primer

Member link: https://connect.incose.org/Library/InsightMagazine --> INSIGHT_v23-2_0629

Objective of Today's Presentation

- To gain feedback on how to assist Systems Engineers in
  - Identifying the many constituent systems that might collectively provide the communications services used by an organization.

Background

- Most modern IT and technology based systems
  - rely heavily on networking to obtain and disperse the information they were designed for.
- Most Systems Engineers know little about the world of modern networking services and capabilities.
  - Many modern solutions rely upon components communicating through networks that are shared between multiple applications and/or are managed by third parties.
  - The nature of those network services requires them to be treated differently than dedicated communications links.

Outcomes

- The primer intends to identify
  - The communications networks
    - that a Systems Engineer may encounter;
  - The unique considerations that should be contemplated
    - when designing a Systems of Systems that rely upon one or more shared communication networks; and
  - Define the basic modeling requirements and techniques
    - when including network services and resources into a systems model.

Example Comms Networks

Definition: Telecommunications

Telecommunications comes from: Greek τῆλε / têle "*from a distance*"; and Latin communicare "*to share*"

SE Handbook v5 (draft):

- Telecommunications is the *exchange of voice or data information* between people and/or things *over a distance* by electromagnetic means.
- Telecommunications includes communications networks owned by **carriers**, **Internet Service Providers (ISP)**, **government agencies** and other **enterprises**, as well as **broadcast networks** (e.g. radio, cable, television) and **over-the-top (OTT) applications** (e.g. messaging, video conferencing and social media applications)
- Telecommunications systems are built on a wide range of technologies: **satellite communications**, **cellular networks**, **land mobile radio**, **microwave**, **radio**, **television**, **Wi-Fi**, **Bluetooth**, and **global navigation satellite systems (GNSS)** and increasingly comprise software

Definitions: CNs, OT + IT = ICT

Communications Networks (CNs) are developed and operated using several key technologies and concepts.

1. Criticality of the CN depends on the application or use;
2. Resiliency of the CN depends on the design or architecture; and
3. Resiliency of the application or service depends on the design of the application or service and may depend on the design of the CN.

Operational Technology (OT) - Hardware and software systems used to change, monitor, or control physical devices, processes, and events within industrial or organizational settings. Historically, OT systems have been stand-alone, machine-language and machine-operated control-systems requiring a high-level of availability with little human interface. OT systems run critical infrastructure (CI) systems, e.g. power, water, rail, etc.

Information Technology (IT) - Broadly referred to anything related to computer technology, including hardware and software systems. CNs have historically been synonymous with telephony, broadcast radio, and mobile phone systems. The physical medium which has connected communication applications (voice, video, data) have evolved from circuit switched leased lines to packet-based technologies running over Internet Protocol (IP).

Information and Communications Technology (ICT) - Emerged to address the convergence of IT and traditional CNs; ICT is generally accepted to mean all technologies that, combined, allow for people and organizations to interact in the digital world.

Implications

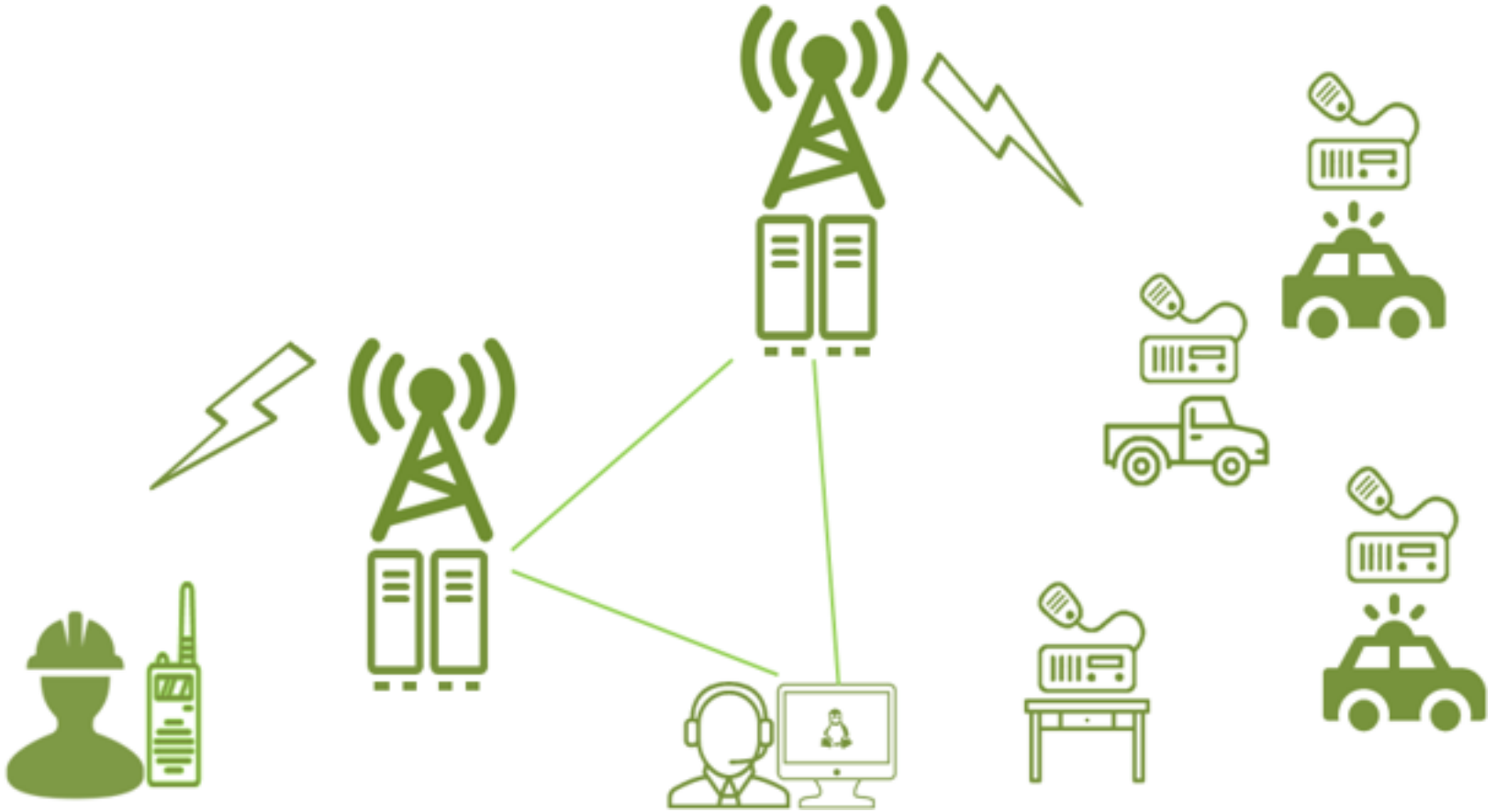
- Communications technologies are becoming *pervasive* in everyday lives
- Communications networks are no longer the exclusive domain of the carriers (if they ever were)
- Communications systems are *components of broader systems* (underpinning Smart Cities, Industry 4.0, AI etc)
- *Cyber Security* is an increasing threat
- Telecommunications is therefore becoming more '*complex*'
- As such, Systems Engineering has much to offer

Why model a network as a system?

While the terms '*System*' and '*Network*' are often used interchangeably in relation to communications networks, in practice, it can be very difficult to define system boundaries or the internal and external interfaces of communications networks as the network topology can be constantly changing.

If it is possible to describe a *network as a system* then, the tools in the *systems engineer's toolkit* can be unlocked to add value to both the design and support of the network.

Example: Communications Networks

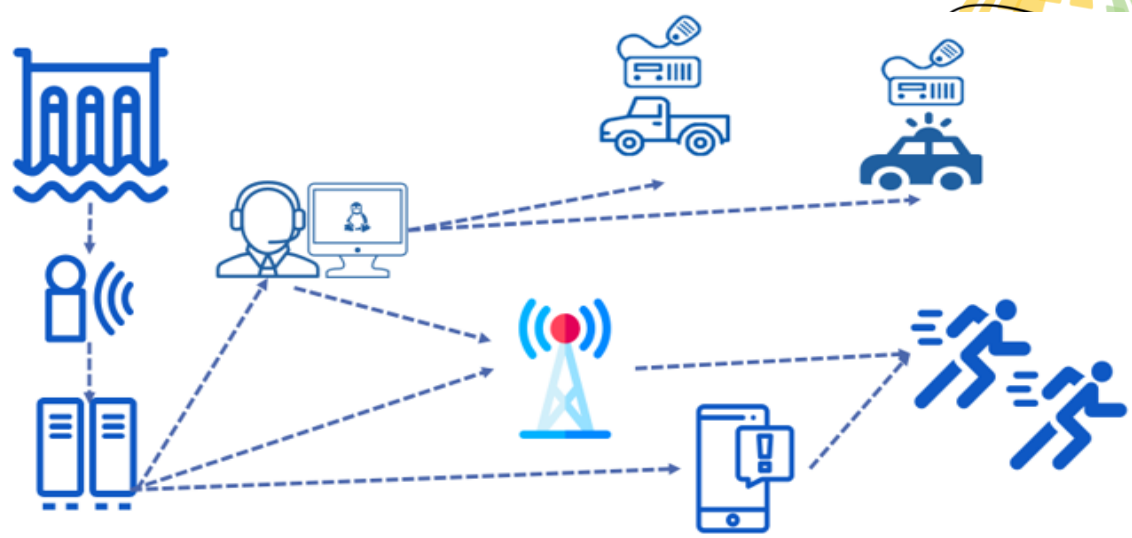


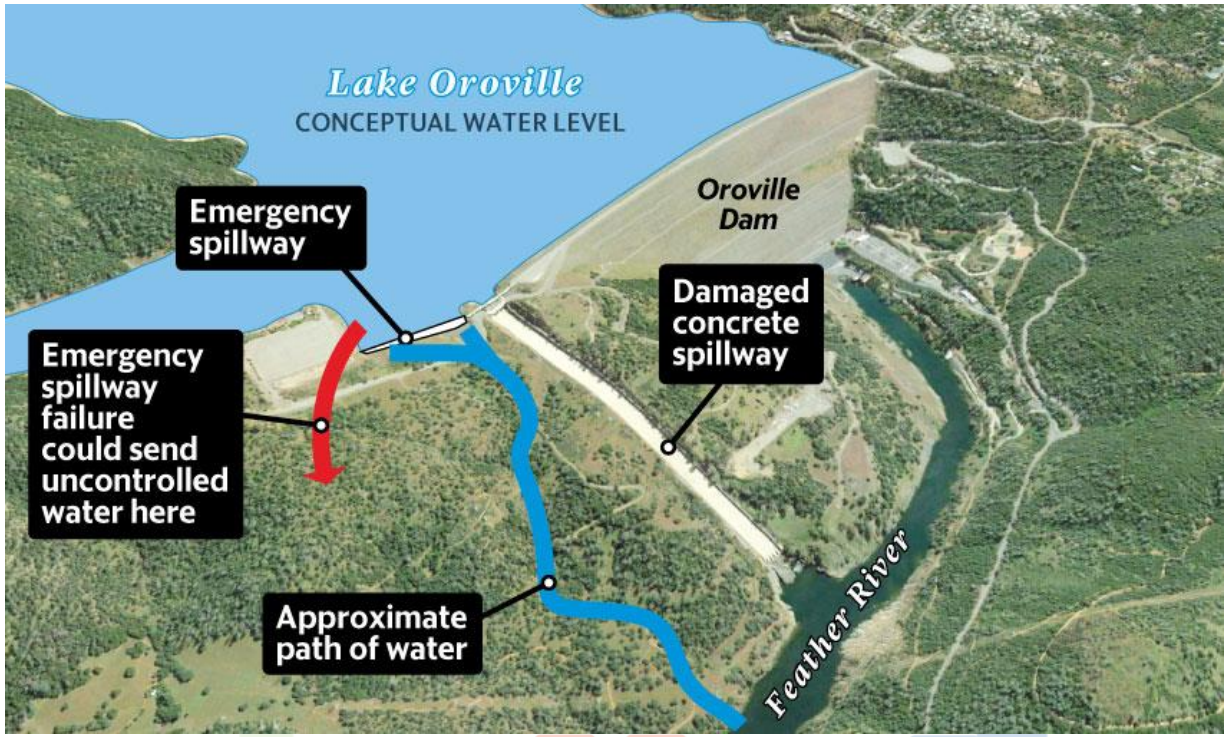
Example:

Cellular or two-way radio system

Alerts & Warnings mitigate loss of life

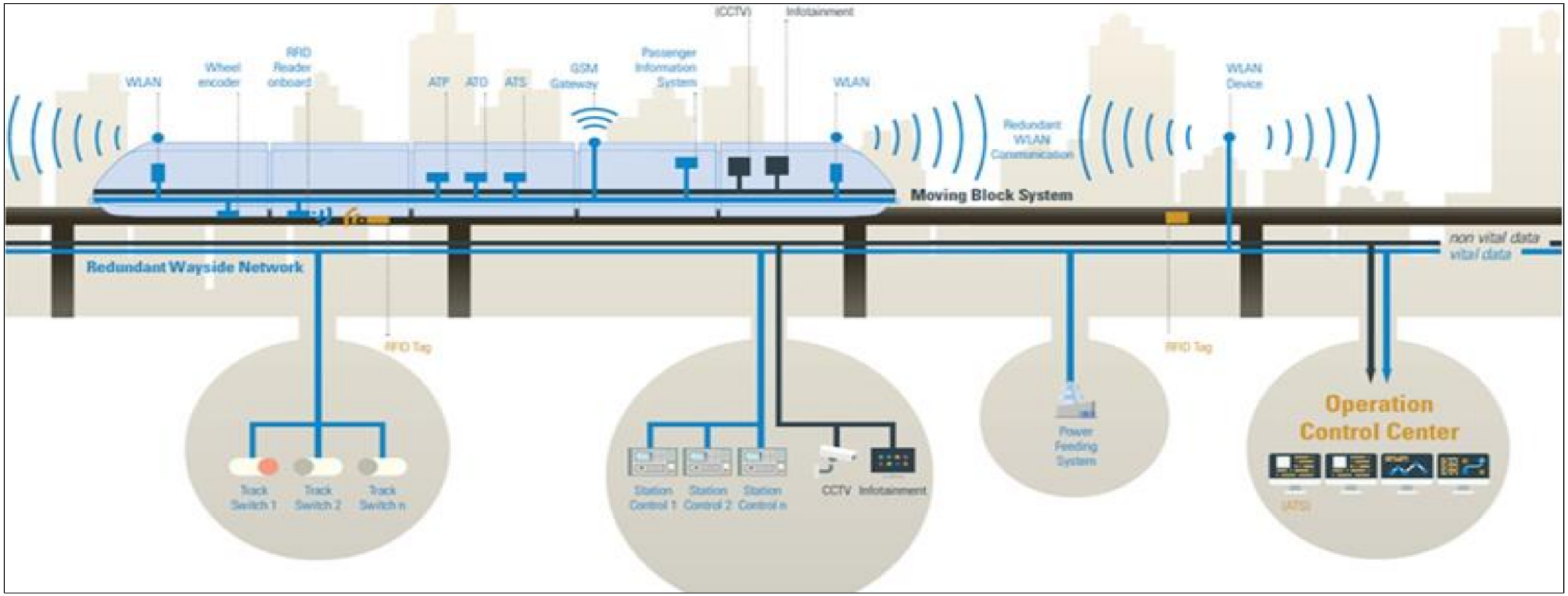
February 2017. Heavy rainfall during damaged the main spillway; overflows prompted the evacuation of more than 180,000 people living downstream.





Credit: The Sacramento Bee

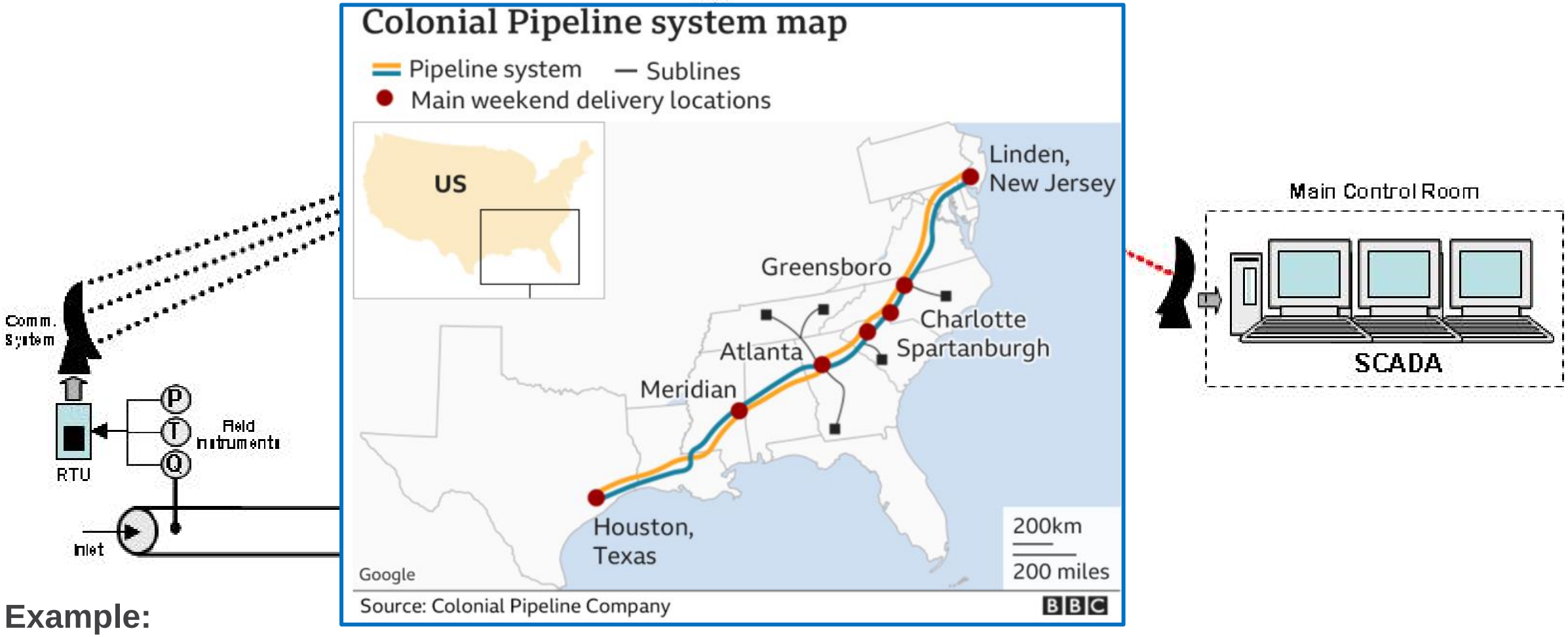
Example: Communications Networks



Example:

Computer based train control

Example: Communications Networks



Example:

Gas pipeline SCADA system (Supervisory Control and Data Acquisition)

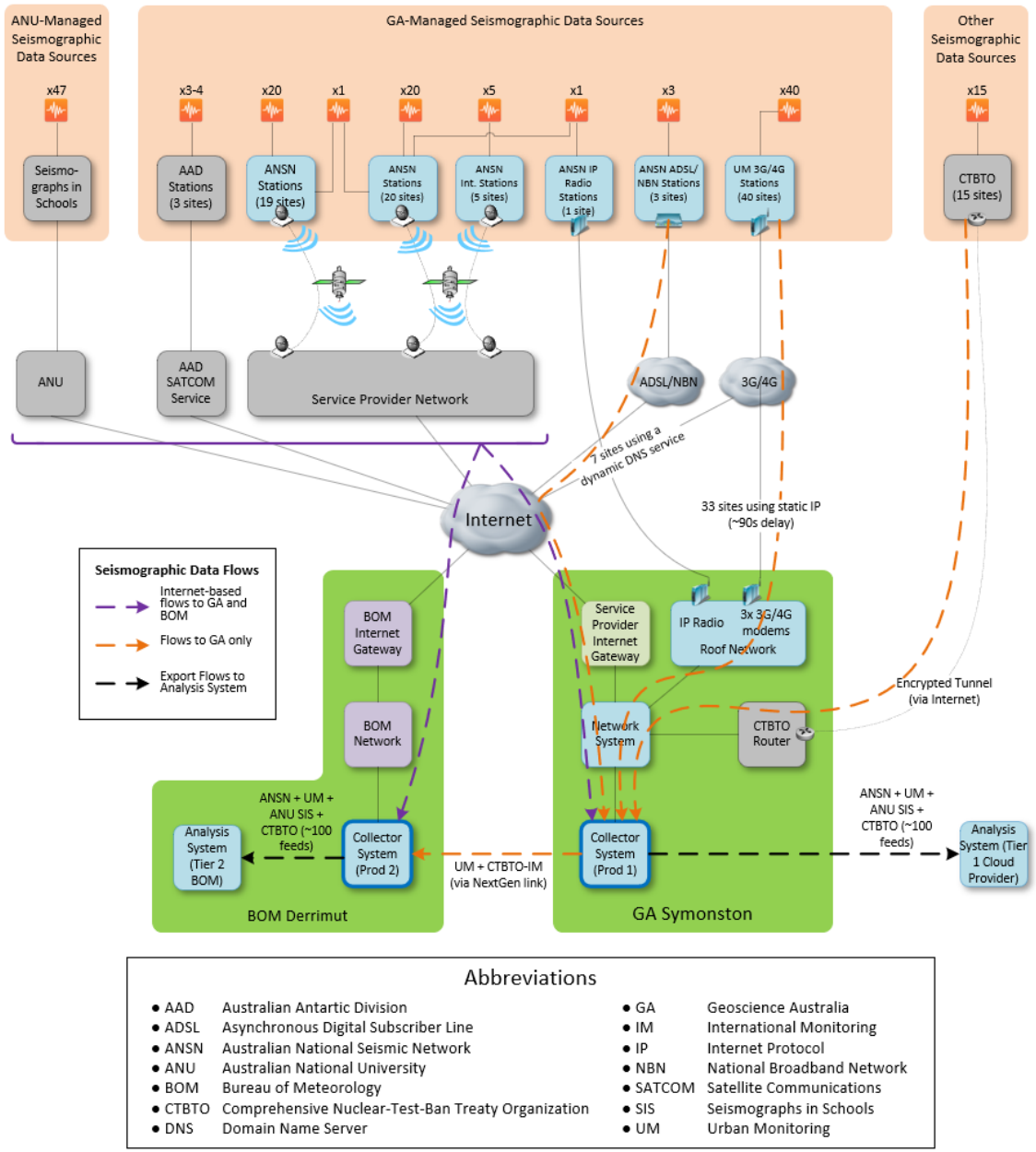
Unique Considerations

Key Aspects of Comm Networks

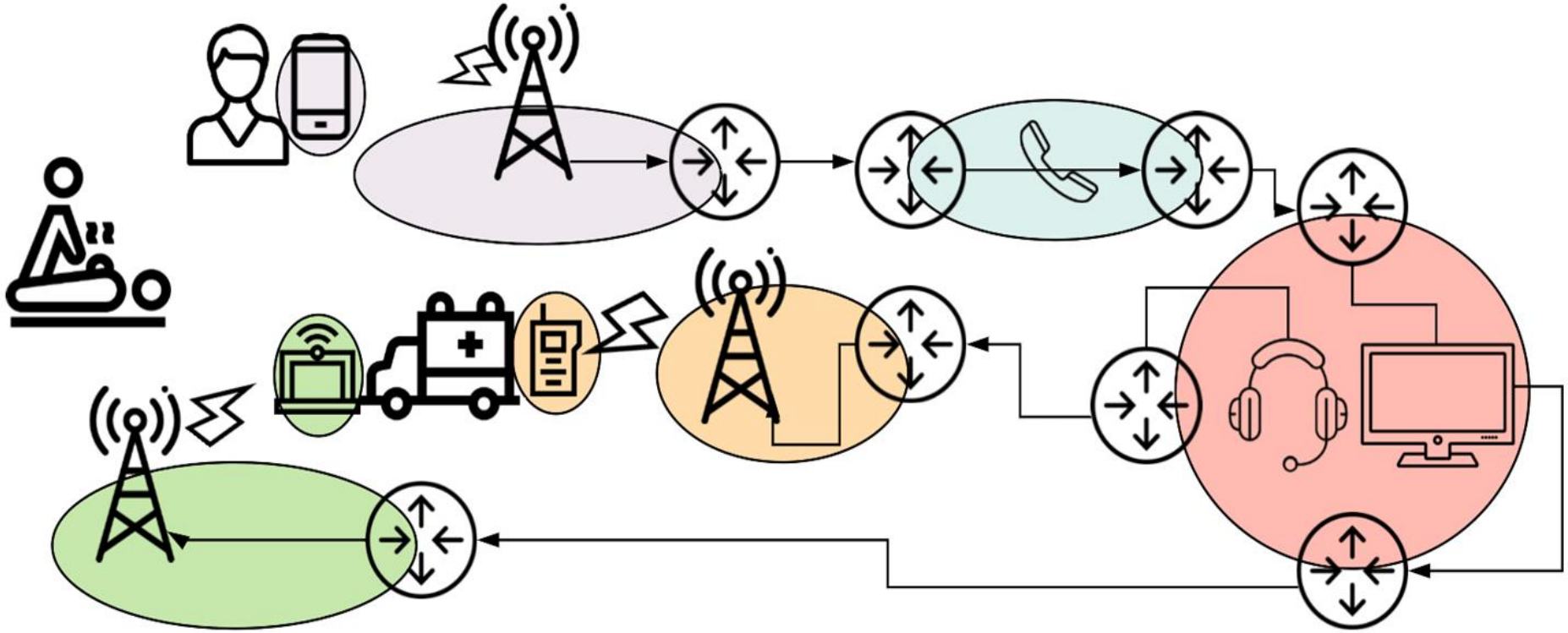
- A CN may actually be made up of a collection of contributing CNs, integrated and interacting with one another (each acting as an independent system)
- A CN may therefore be owned, maintained, and managed by different entities, all working together to transport information from one location to another
- Each individual system – independently and together – must be designed to withstand potential failures.

Example: Tsunami Warning System

CN	Distributed Systems (Step 2)	Impacts (Step 4)	Criticality (Step 4)
1	GA Corporate Network	ATWS outage	Highest criticality
2	Collector System	ATWS outage	Highest criticality
3	Analysis System	ATWS outage	Highest criticality
4	Sensor System	ATWS degradation	Highest criticality
	Twitter		
	Twilio		
	Email		
	Bearer Networks (Step 2)		
5	3G/4G (Provider 3)	Sensor data degradation (40 Australian sites)	Medium criticality
6	Internet	Sensor data degradation (121 Australian, Antarctica and international sites), alerts outage,	Highest criticality
7	Satellite (Provider 1)	Sensor data degradation (3 Antarctica sites)	Lowest criticality
8	Satellite (Provider 2)	Sensor data degradation (43 sites)	Medium criticality
9	Radio IP	Sensor data degradation (1 Australian site)	Lowest criticality
10	ADSL/NBN	Sensor data degradation (3 Australian sites)	Lowest criticality



Example: Communications Networks



Emergency Medical Services Communications Network

Manley, Thomas, Susan Ronning, and William Scheible. "Defining Critical Communications Networks: Modelling Networks as Systems."*INSIGHT*23, no. 2 (2020): 36-42

Examp

Emergency medical call from mobile phone service via commercial telephone system to public safety answering point to ambulance via voice radio and broadband data networks – This demonstrates multi-bearer networks in everyday occurrence

Modeling Techniques

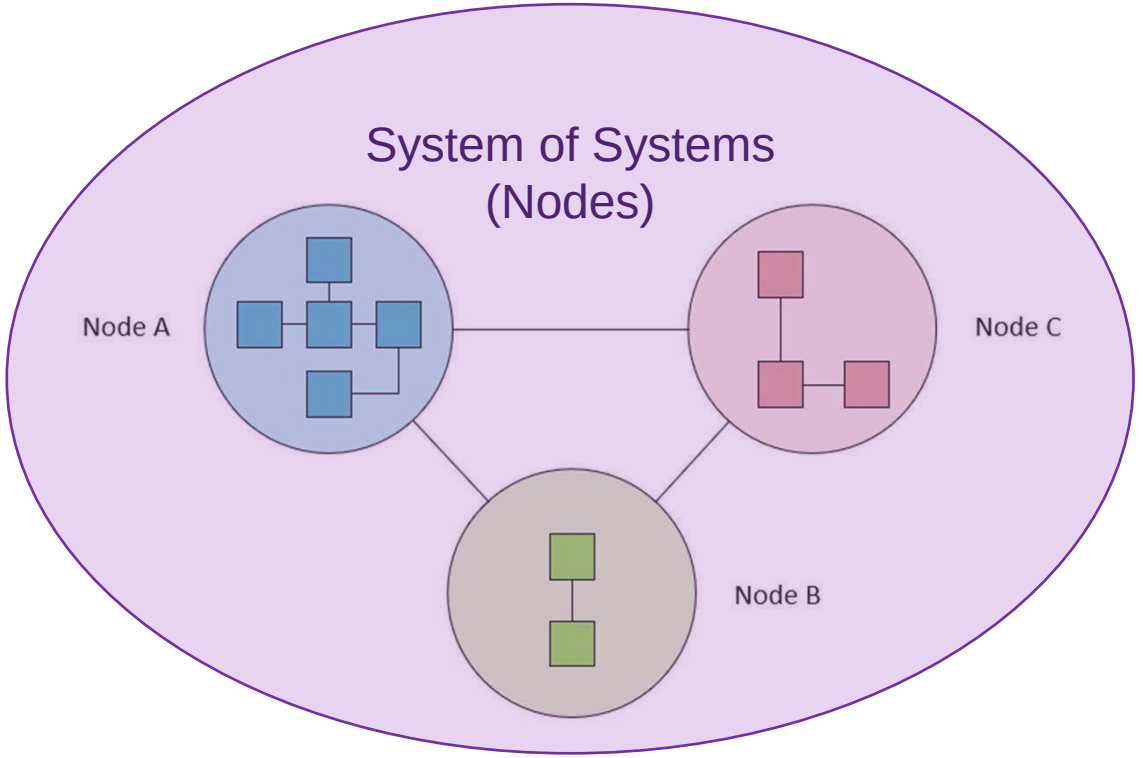
Nodes and Links

Communications Networks are often modelled as a set of interconnected sites or locations. In this case, each site/location becomes a Node. Nodes could be:

- **Fixed site**, such as a building or university campus.
- **Mobile location**, such as vehicles that move on the ground, under the sea, in the air, or in space
- **Person or Animal**, if carrying or wearing a communications device.

Nodal recursion is also possible, such that there could be (intra-node) communication within Nodes and (inter-node) communication between Nodes.

Each Node can be treated as a **Nodal System** in its own right.



Example nodes showing internal and external structure with i) inter-node links / external interfaces and ii) intra-node links / internal interfaces.

Communications Networks are Systems of Systems (SoS)

Systems of Systems (SoS) tend to have the following characteristics (from the SE Handbook 4th ed.):

- Operational independence of constituent systems
- Managerial independence of constituent systems
- Geographical distribution
- Emergent behavior
- Evolutionary development processes

We postulate that Communications Networks also exhibit the following characteristics:

- **Common purpose**;
- **Commonality of architecture**;
- **Strong interdependence of constituent systems** (e.g. failure of an email server);
- **Large in scale**; and
- A strong focus on **traffic flows** through a network rather than the interfaces within it.

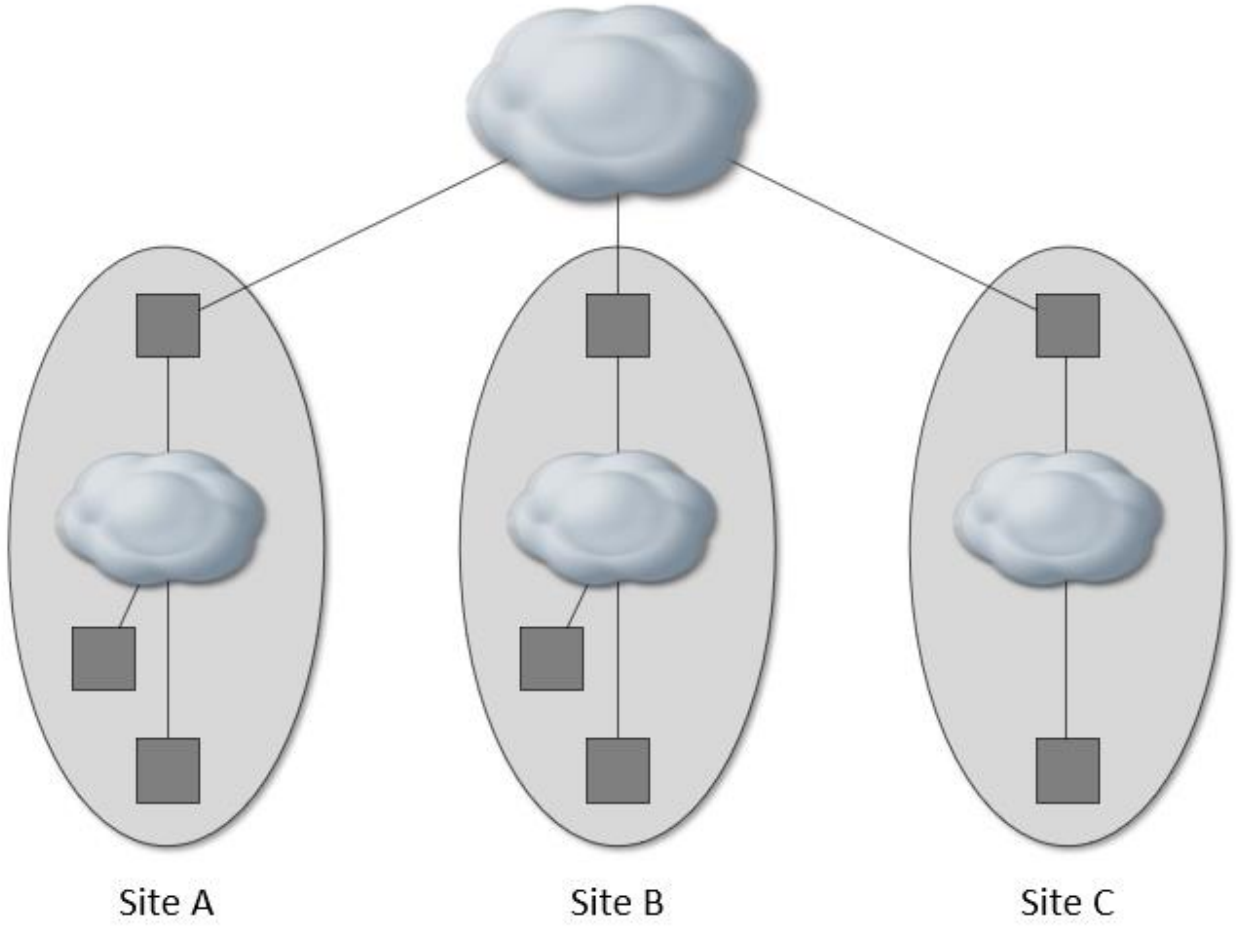
Functional Systems

- **Bearer Networks**: those functional systems whose main purpose is to connect nodes (e.g. a WAN)
- **Distributed Systems**: systems whose elements operate together irrespective of geographical distribution or are at least managed as one system.

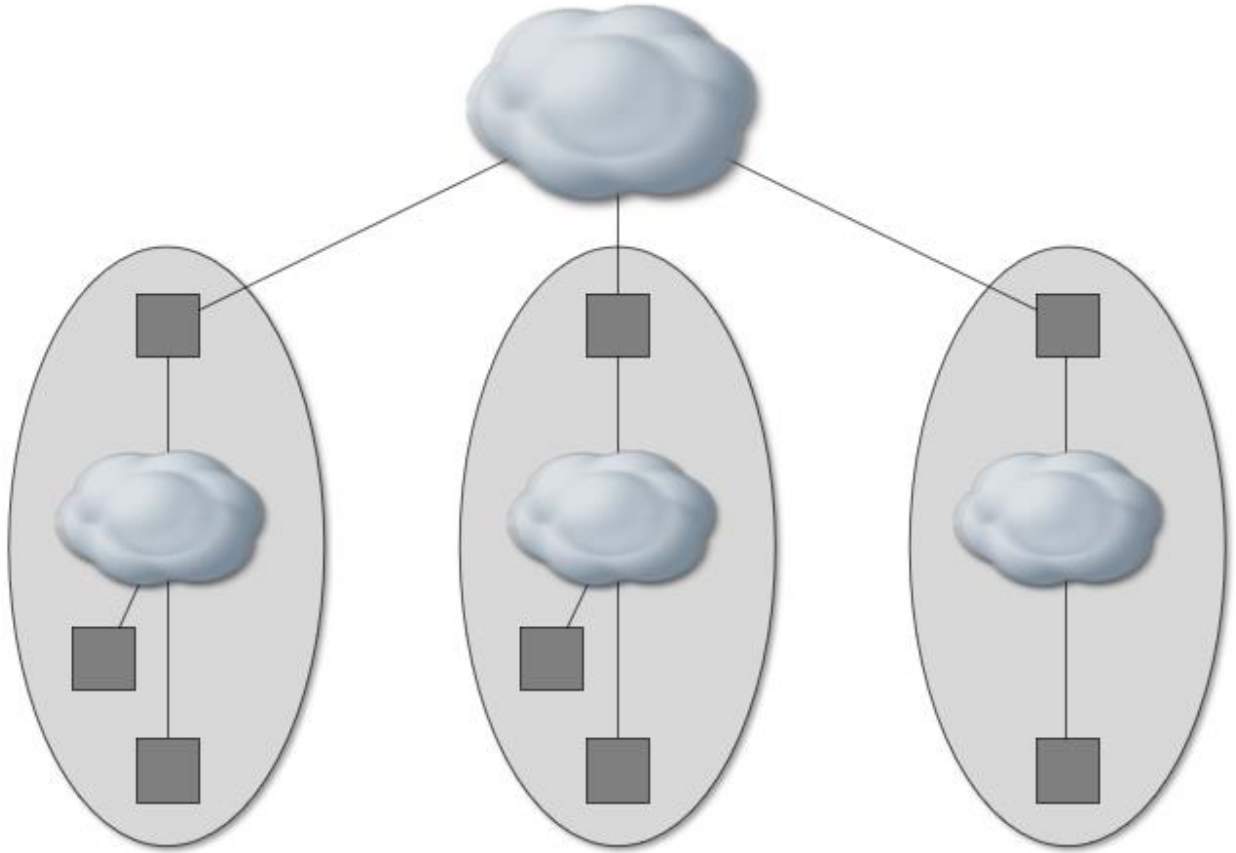
The implication is that solution elements (as technology building blocks) may simultaneously be a subsystem of a node as well as a subset of a functional system.

This dual nature of a solution element is a property of communications networks that requires new thinking.

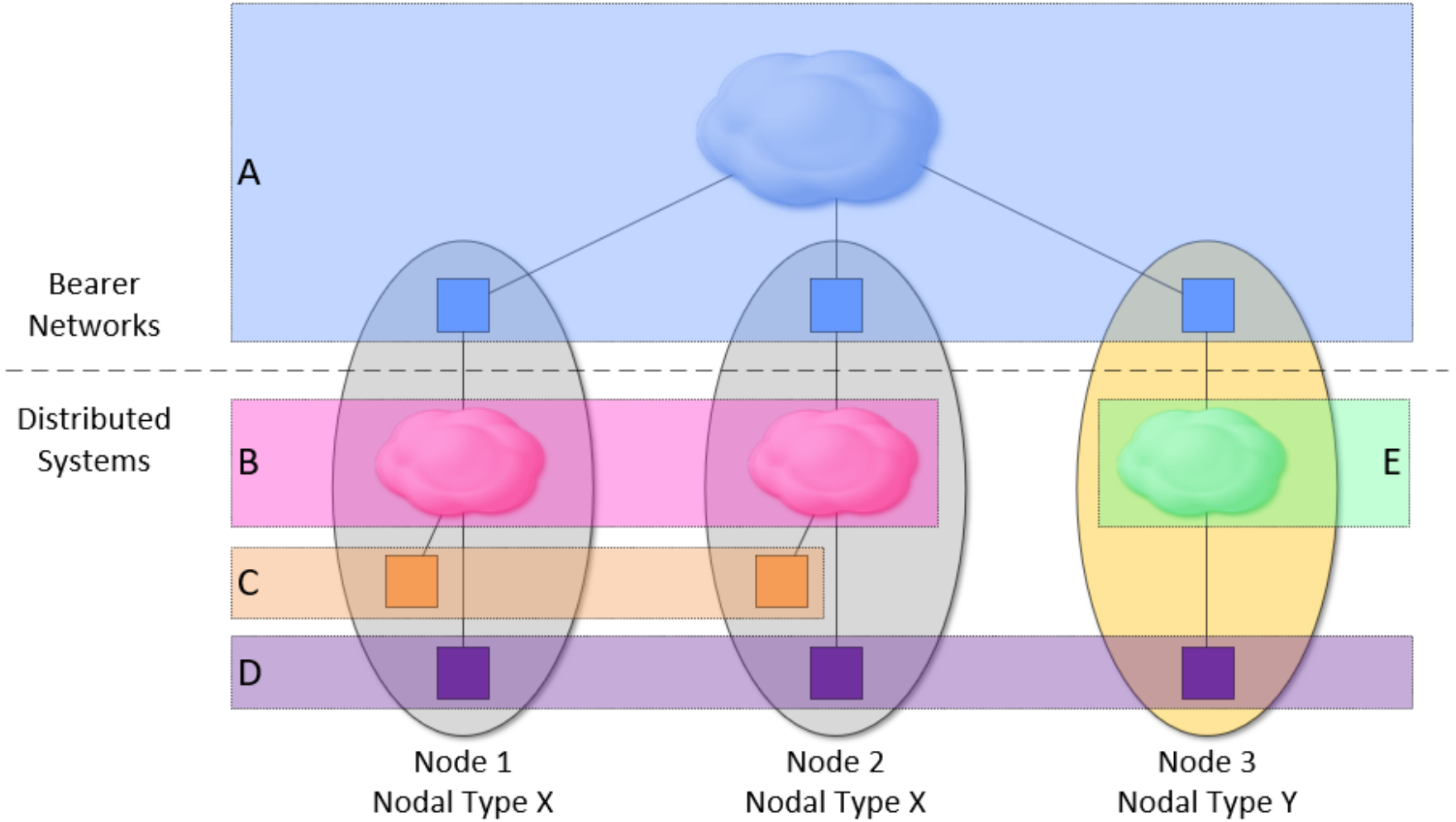
Example: Three Site Topology



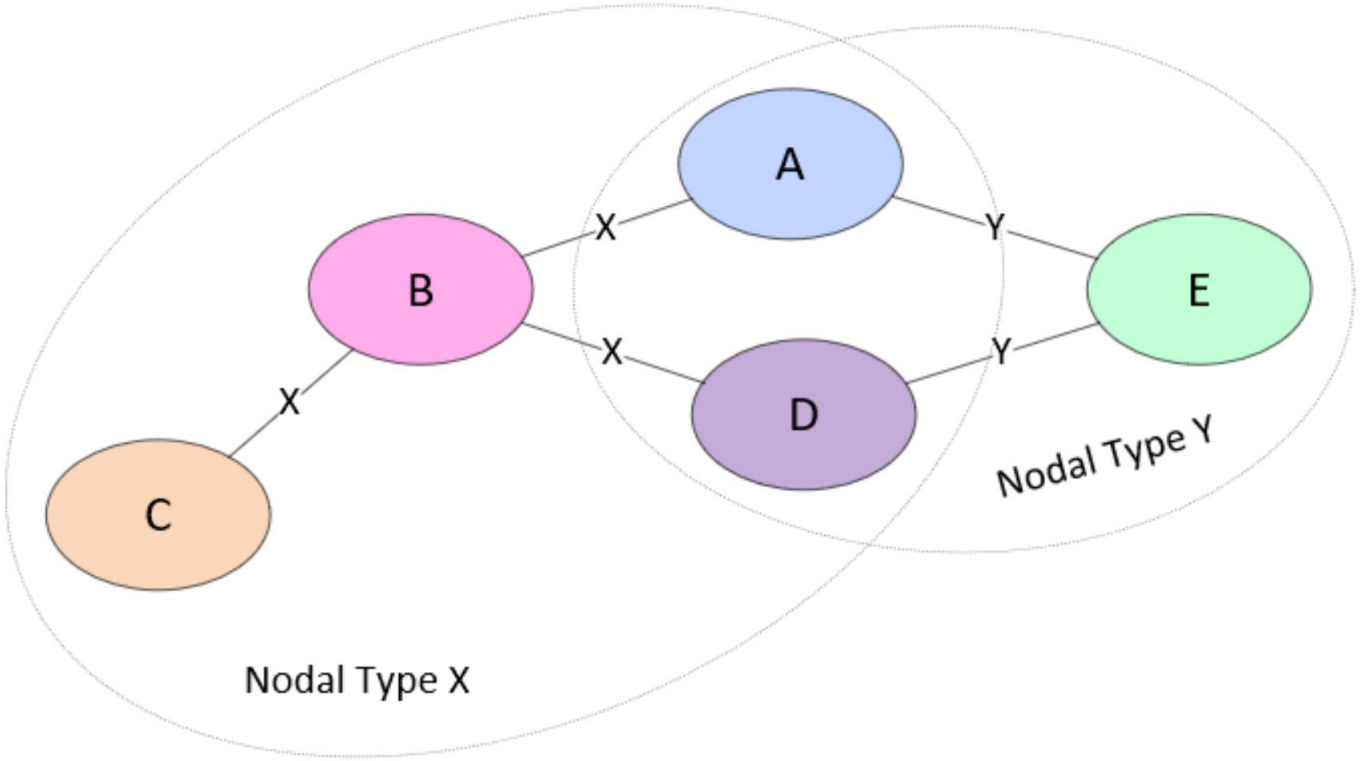
1. Identify Nodal Types



2. Identify Functional Systems



3. Inter-Functional System Interfaces



Tailoring of IEEE 15288

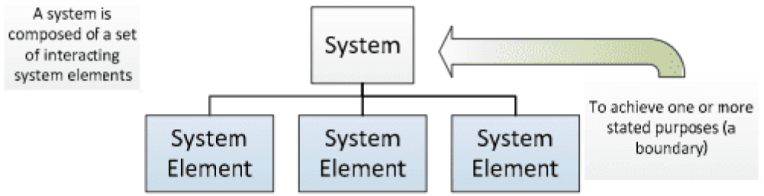
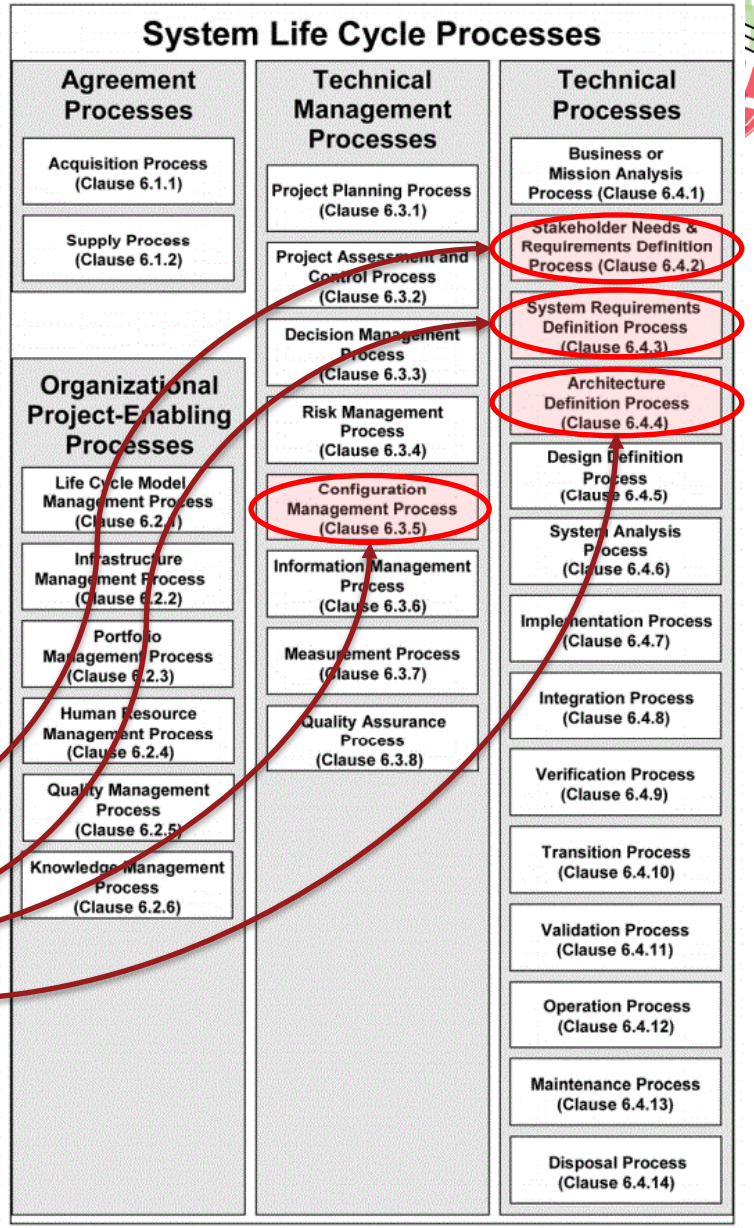


Figure 1 — System and system element relationship

- 5 Key concepts and application of this International Standard
  - 5.2 System concepts
    - **5.2.2 System structure** – *modeling networks as systems*
- 6 System life cycle processes
  - 6.3 Technical management process
    - **6.3.5 Configuration management process**
      - 6.3.5.3 Activities and tasks
        - » b) Perform configuration identification – *logical Configuration Items (CI)*
  - 6.4 Technical Processes
    - **6.4.2 Stakeholder needs and requirements definition process** – *stakeholder identification*
    - **6.4.3 System requirements definition process** – *functional boundary and functions*
    - **6.4.4 Architecture definition process** – *architecture viewpoints, context, boundaries, interfaces*
- Annex F Architecture modeling
  - F.3 Logical and physical models
    - F.3.7 Network model (“arrangement of nodes and links”) – *network model*



Next Steps

- Recap: The primer intends to identify
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    - when designing a Systems of Systems that rely upon one or more shared communication networks; and
  - Define the basic modeling requirements and techniques
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- Feedback Request
  - How can the Telecommunications WG assist YOU in your work?
  - Are we hitting the right mark? Suggestions on what to consider or use as examples?

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Contact

Thomas Manley, CPEng., CSEP
thomas@manley.name
https://www.linkedin.com/in/manleythomas/

Dr. Keith Rothschild
Keith.Rothschild@cox.com
https://www.linkedin.com/in/krothschild/

Susan Ronning, P.E., PMP
s.ronning@adcomm911.com or susan.ronning@incose.net
https://www.linkedin.com/in/susanronning/

William Scheible, ESEP
wscheible@mitre.org or Bill.Scheible@incose.net
https://www.linkedin.com/in/william-bill-scheible-29a6703/