33rd Annual INCOSE international symposium

hybrid event

Honolulu HI USA

Telecommunications Primer

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INCOSE ICT WG Members

Other Contributing Members:

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Background and History

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A Criticality Framework for Resilient Communications Networks (unpublished)

Name Change ICT Working Group

2022-23

Telecommunications Primer

Development and publication of a Telecommunications Primer

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

INCOSE Vision 2035

Evolving the Practice of Systems Engineering

"Systems engineering was applied to address the growing challenges of the aerospace, defense, and telecommunications industries."

"These global socio-economic megatrends shape the needs and expectations for systems, providing products and services across all industries and domains such as transportation, health care, space utilization, communications, energy production and distribution…."

The primer intends to:

- Identify the communications network types that a Systems Engineer may encounter;
- Identify the unique considerations that should be contemplated when designing a Systems of Systems that rely upon one or more shared communication networks; and
- Provide guidance on basic modeling requirements and techniques when including network services and resources into a systems model.

Intended to be framed around a tailoring of IEEE 15288:2015/2023.

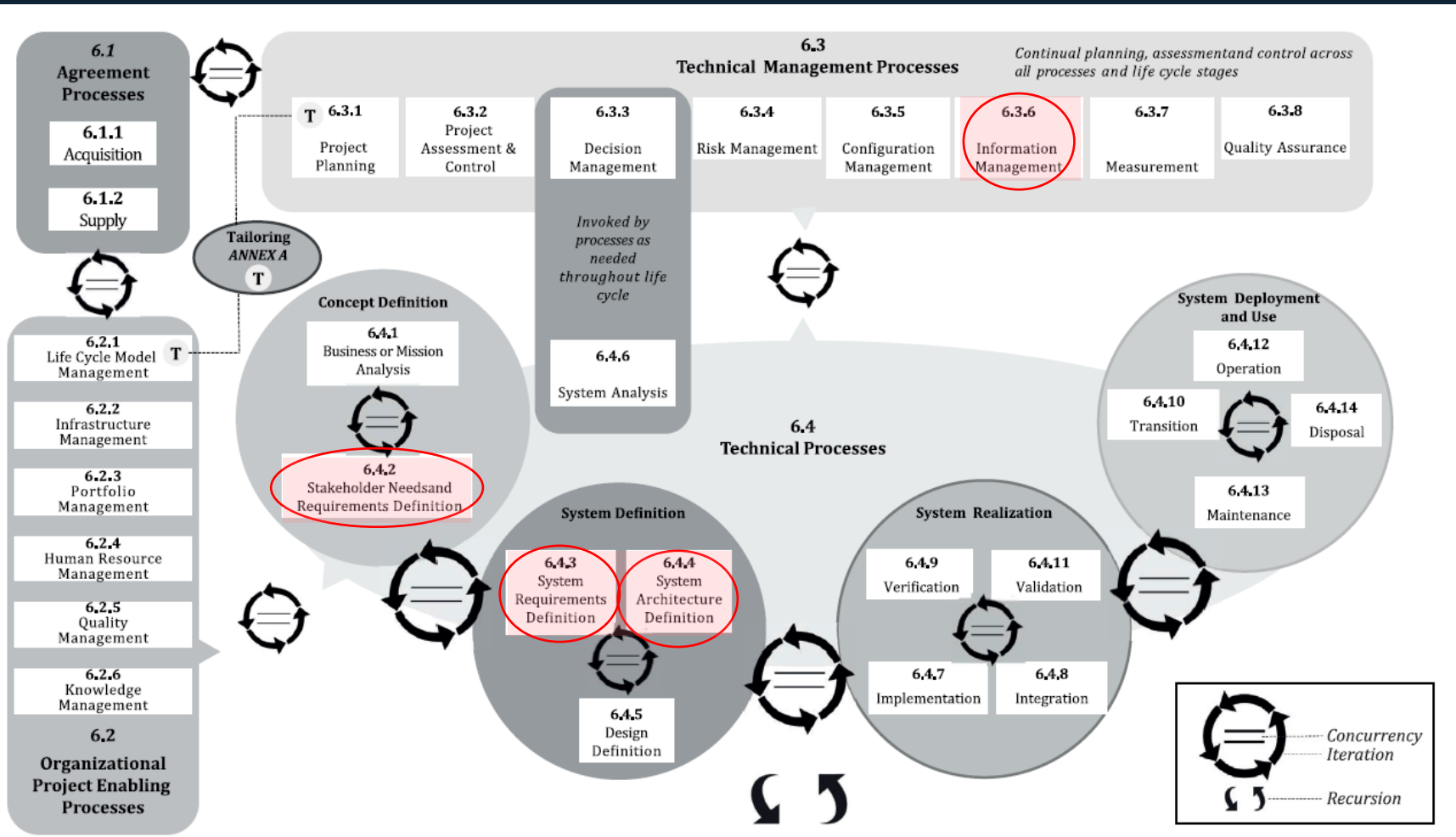


Figure 5 — Interrelationships between processes

ISO/IEC/IEEE 15288:2023

What is Telecommunications?

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

Our Definition

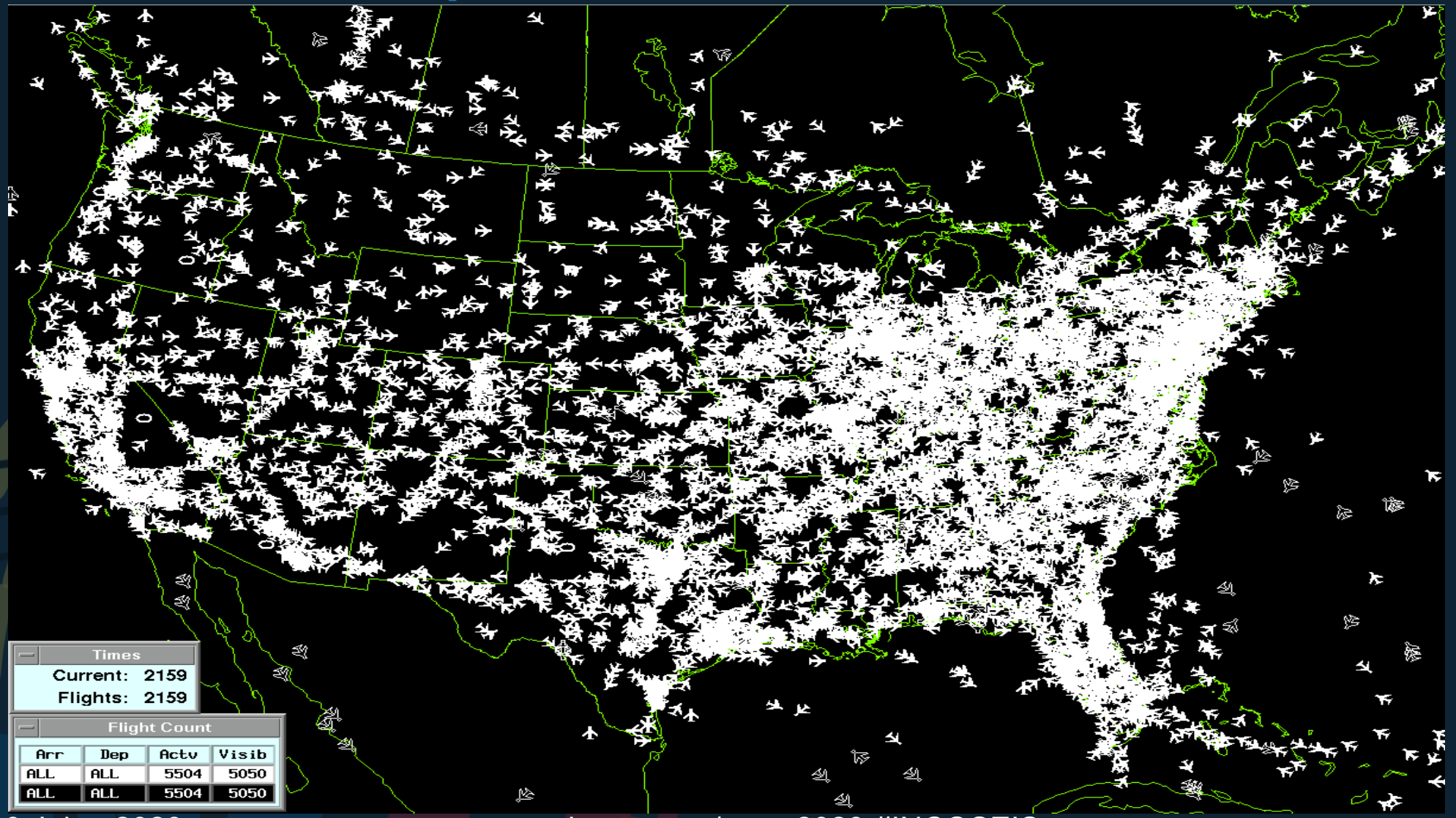
Telecommunications is the *exchange of voice or data information* between people and/or things *over a distance* by electromagnetic means.

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)

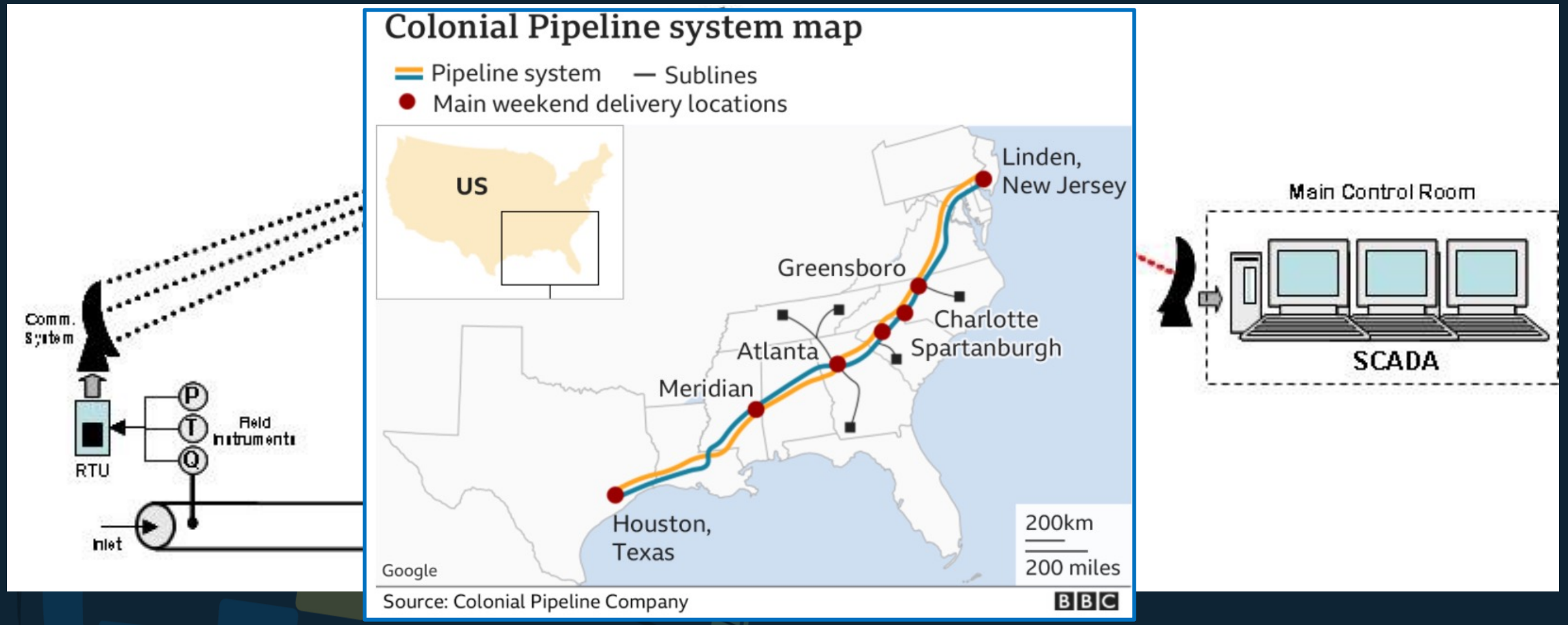
Telecommunications systems are built on a wide range of technologies: **satellite communications**, **cellular networks**, **land mobile radio**, **microwave**, **radio**, **television**, **Wi-Fi**, **Bluetooth**, and **global navigation satellite systems (GNSS)** **and increasingly comprise software**

What are Communications Networks?

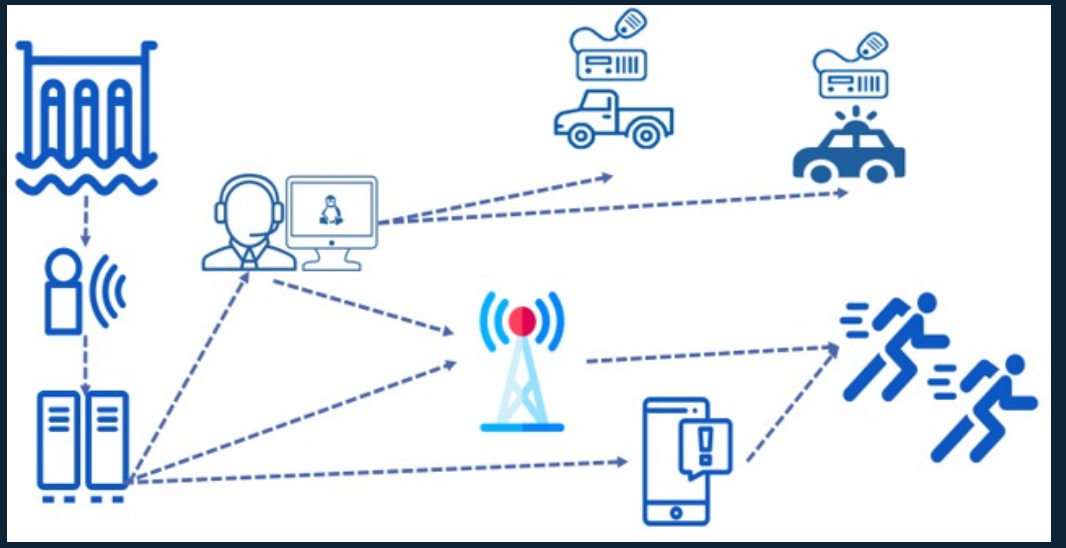
Critical Transport : Air, Land, Water

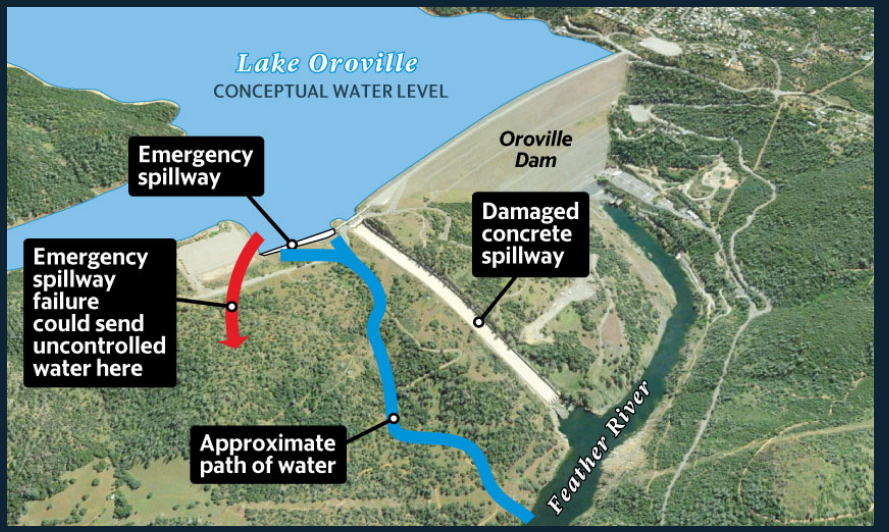


Critical Utilities: Electric, Oil, Gas, & Water

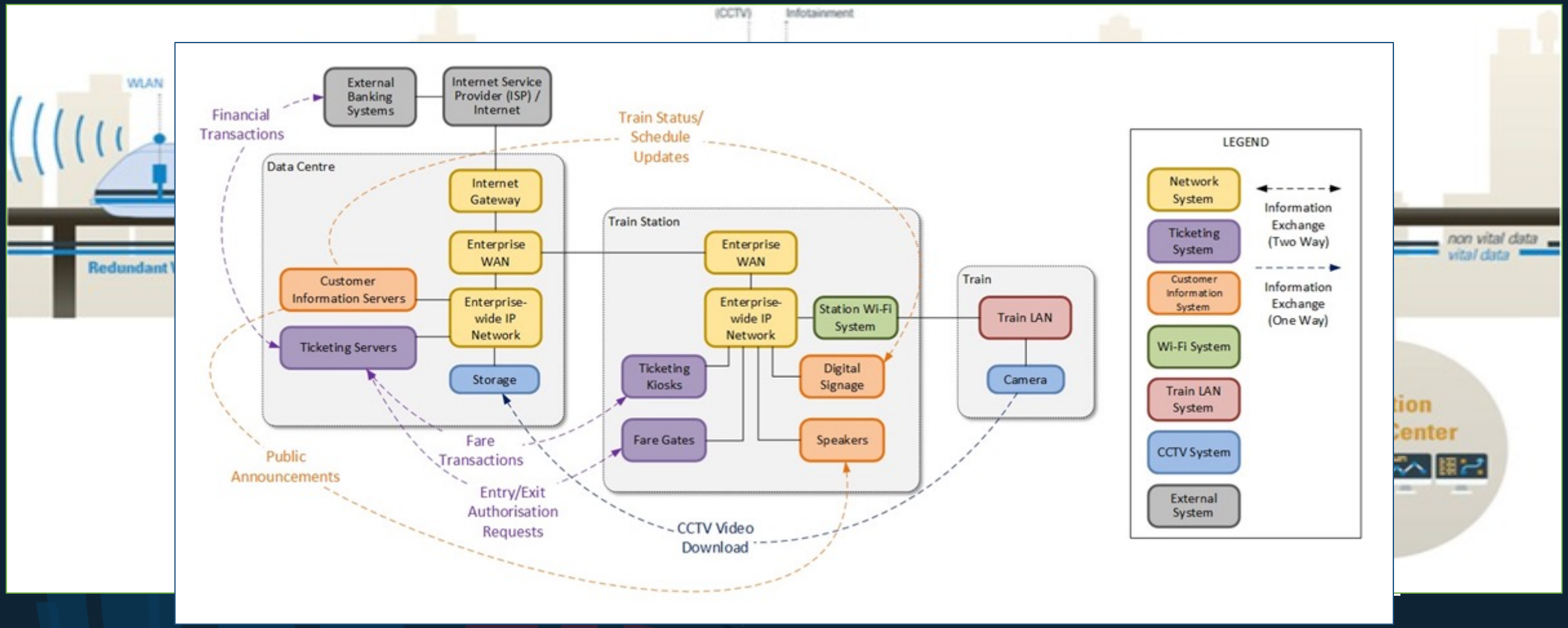


Emergency Alarms & Notifications

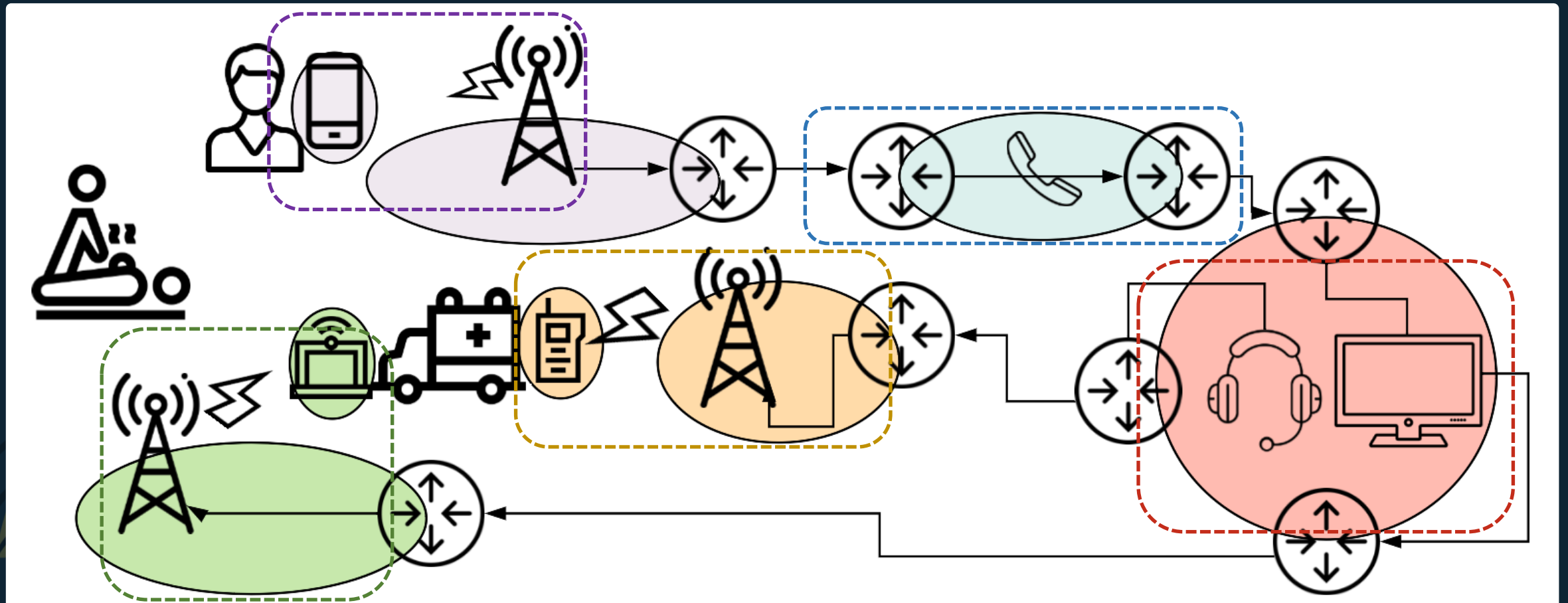




Enterprise Networks



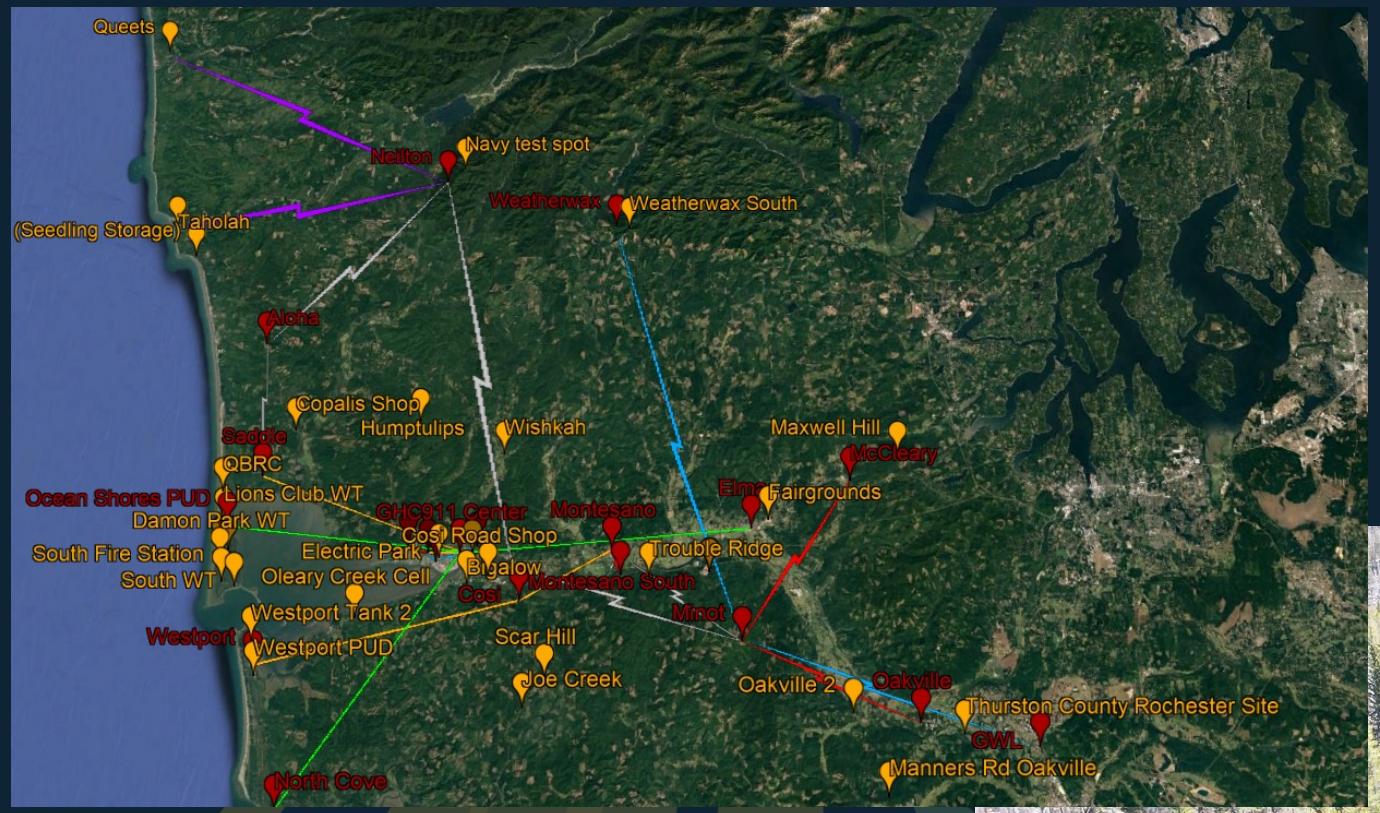
Public Safety Networks



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

Credit: ADCOMM Engineering LLC



Credit: ADCOMM Engineering LLC

Network Concepts

Unique Considerations

- Recursion: A communications network may be constituted by a collection of communications networks, integrated and interacting with one another (each acting as an independent system).
- Decentralised Control: Communications networks may therefore be owned, maintained, and managed by different entities, all working together to transport information from one location to another.
- Diverse Technology: These networks often utilise disparate technologies and capabilities.
- Resilience: Each individual system – independently and together – must be designed to withstand potential failures.
- Brownfield: Most systems already exist is some form – any upgrades or changes will likely impact people or systems

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.

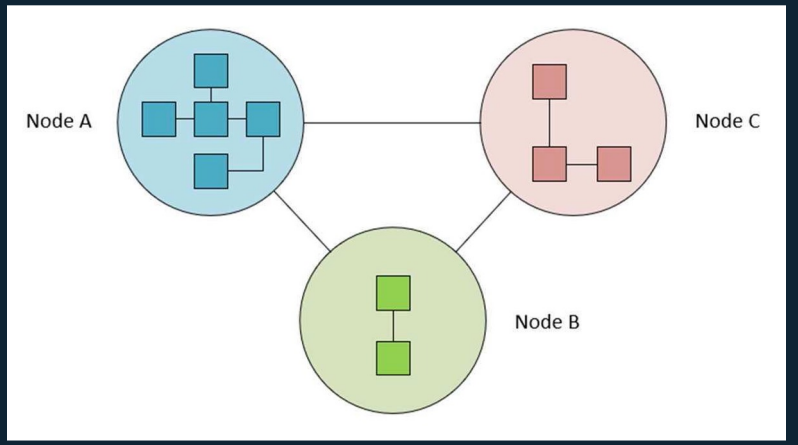
Communications Networks are Systems of Systems (SoS)

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:

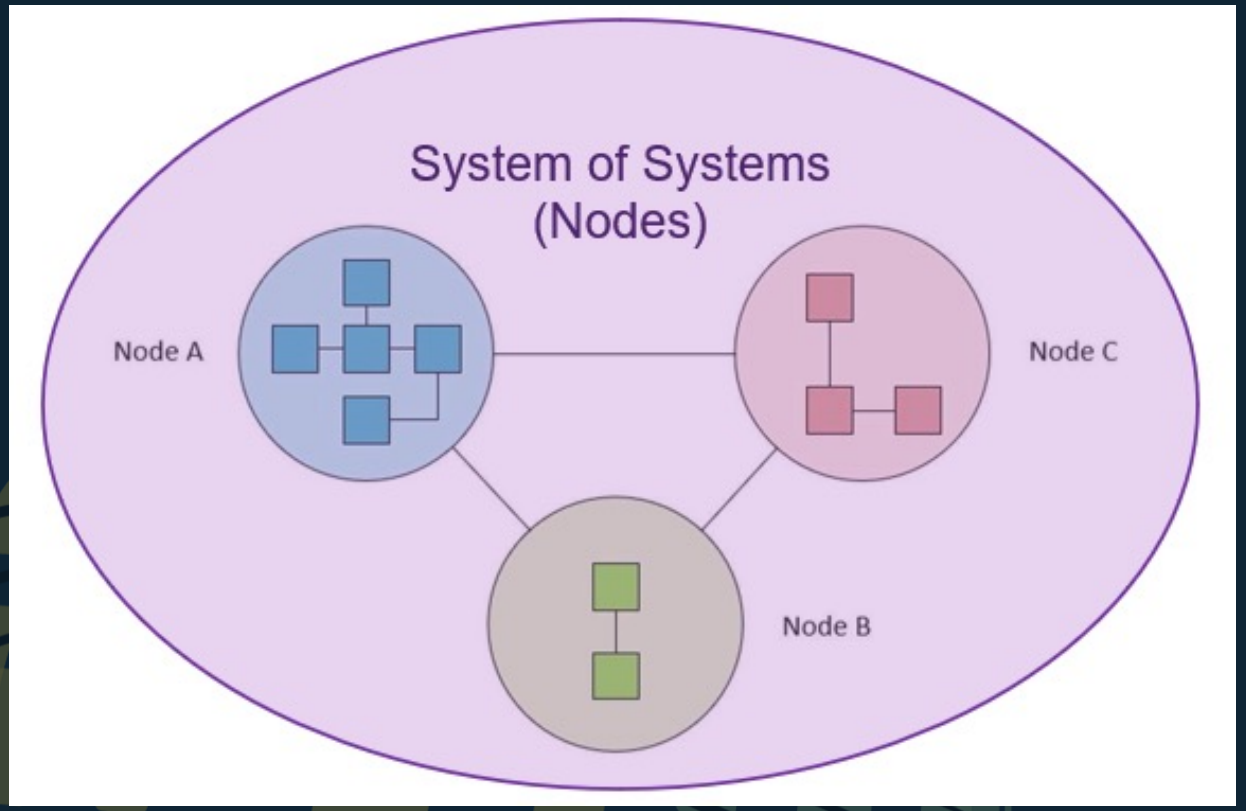
- Fixed site, such as a building or university campus.
- Mobile location, such as vehicles that move on the ground, under the sea, in the air, or in space
- Person or Animal, if carrying or wearing a communications device.

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.



System of Systems



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:

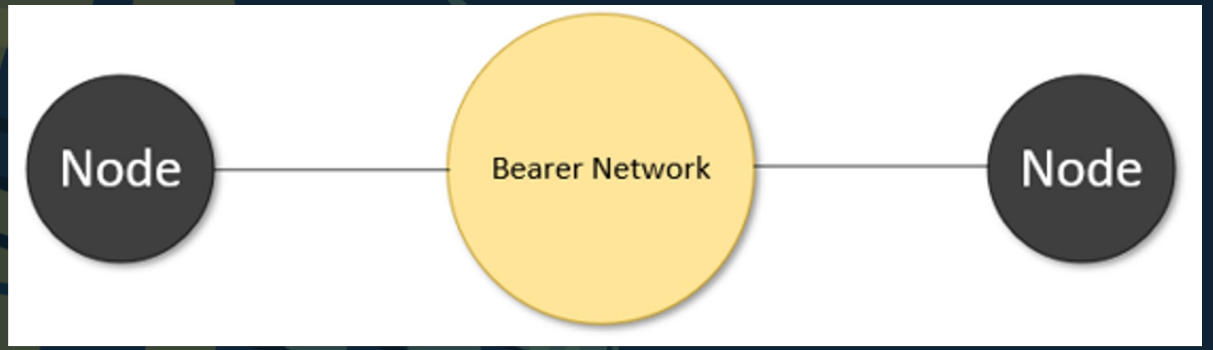
- Common purpose;
- Commonality of architecture;
- Strong interdependence of constituent systems (e.g. failure of an email server);
- Large in scale; and
- A strong focus on traffic flows through a network rather than the interfaces within it.

System Structure

Functional Systems

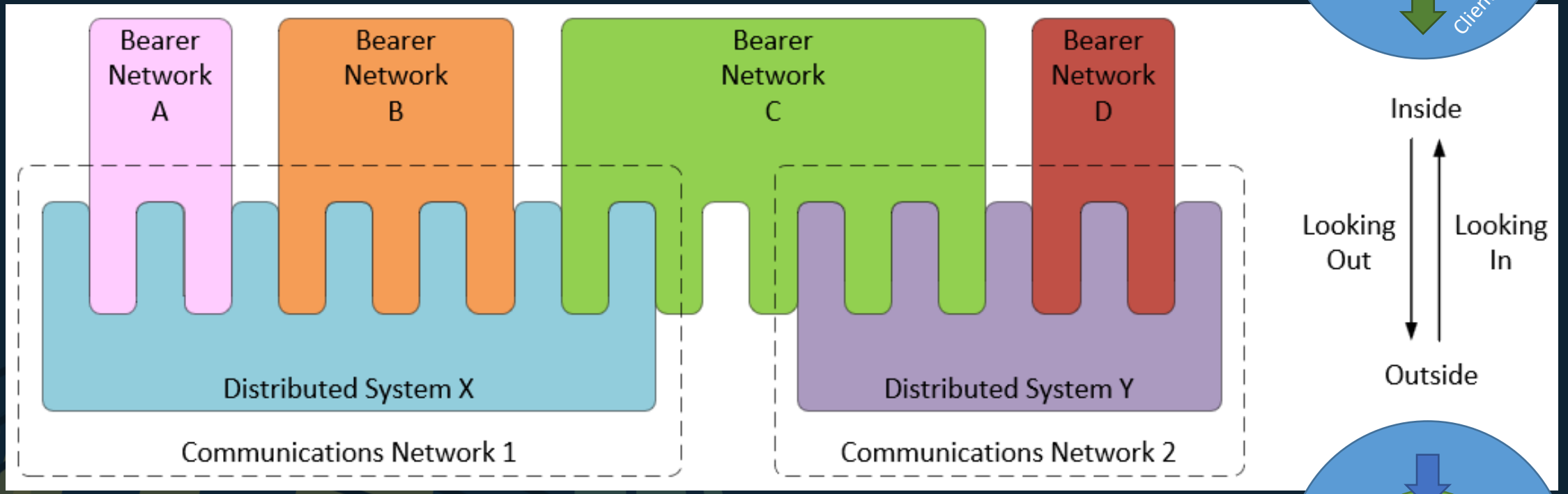
- **Bearer Networks**: those functional systems whose main purpose is to connect nodes (e.g. a WAN)
- **Distributed Systems**: systems whose elements operate together irrespective of geographical distribution or are at least managed as one system.

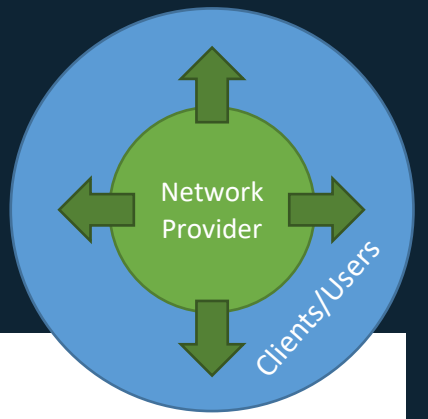
The implication is that solution elements (as technology building blocks) may simultaneously be a subsystem of a node as well as a subset of a functional system.

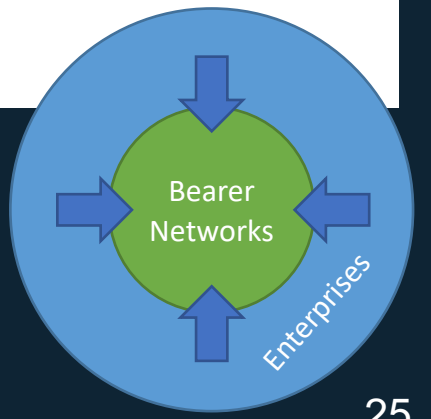


This dual nature of a solution element is a property of communications networks that requires new thinking.

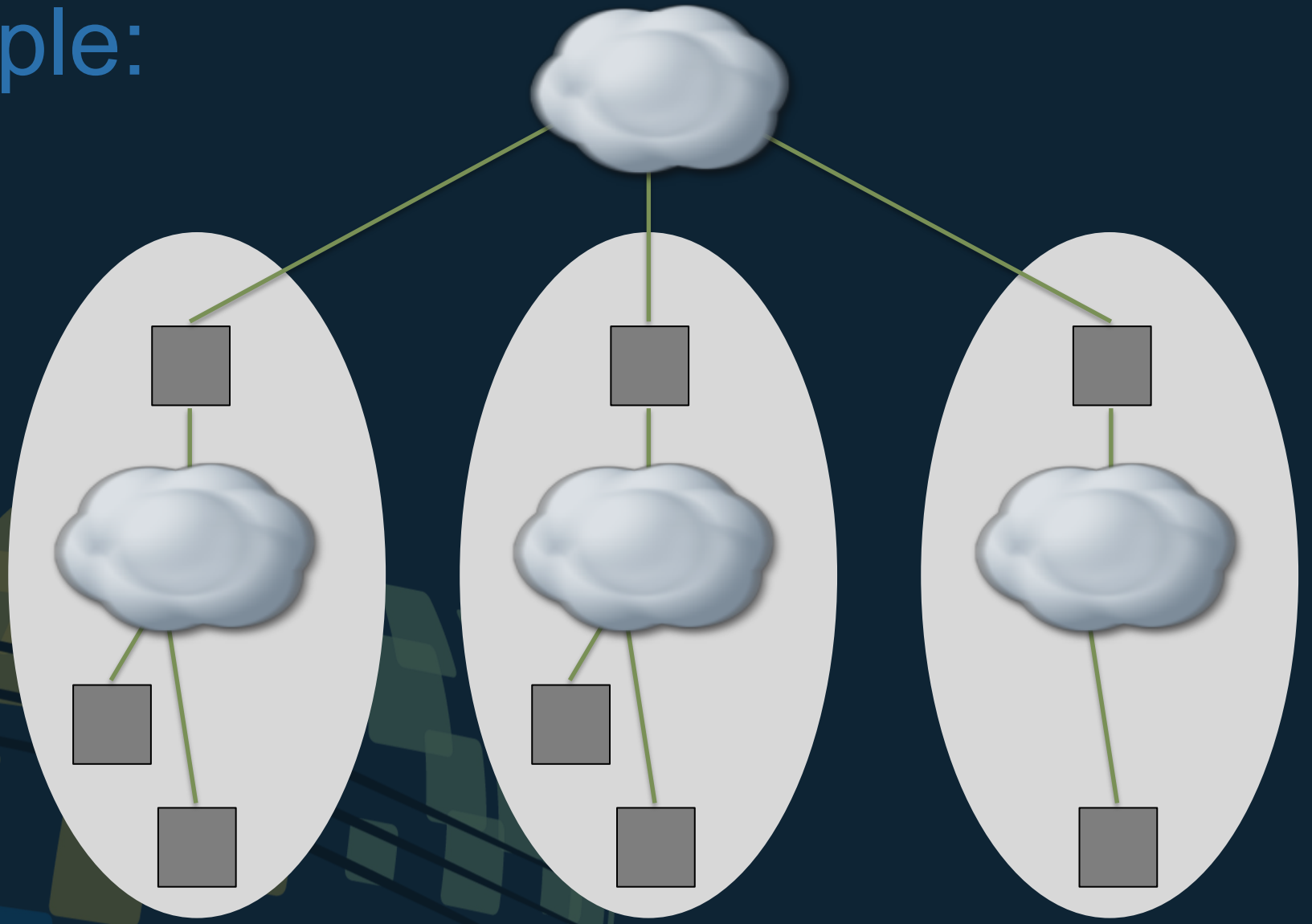
Different Perspectives

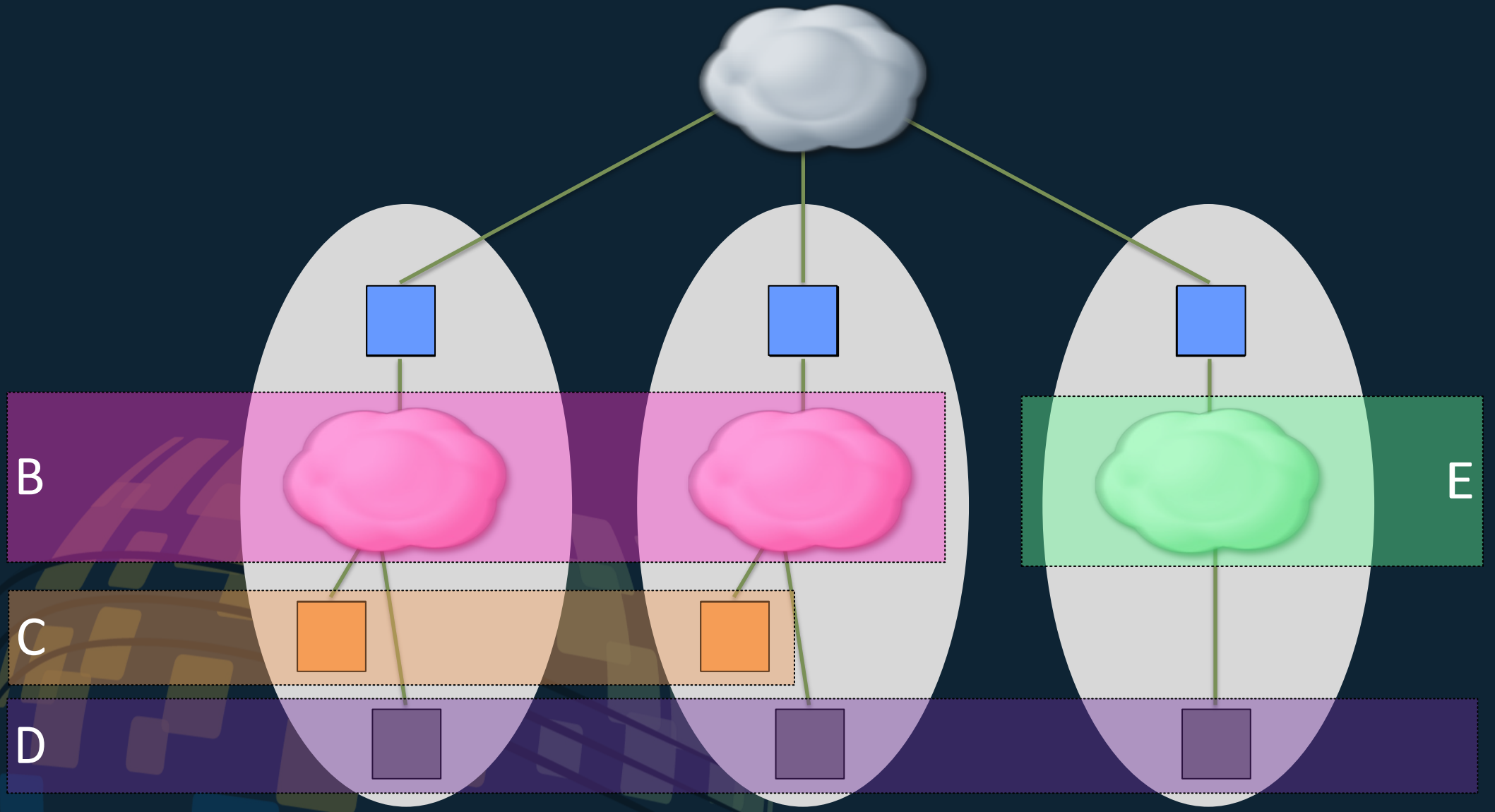


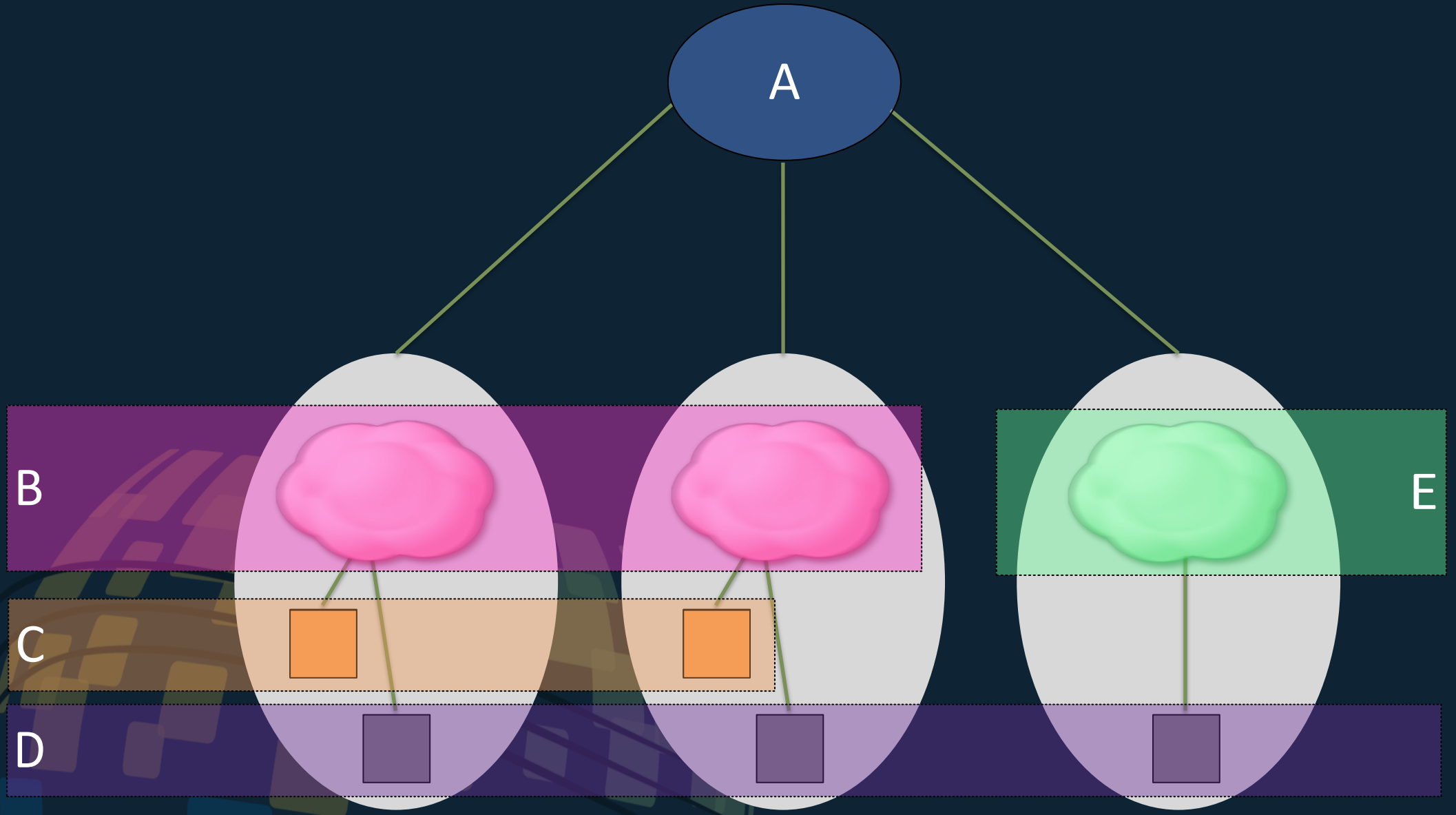




Example:




B
E
C
D
Node 1 Type X
Node 2 Type X
Node 3 Type Y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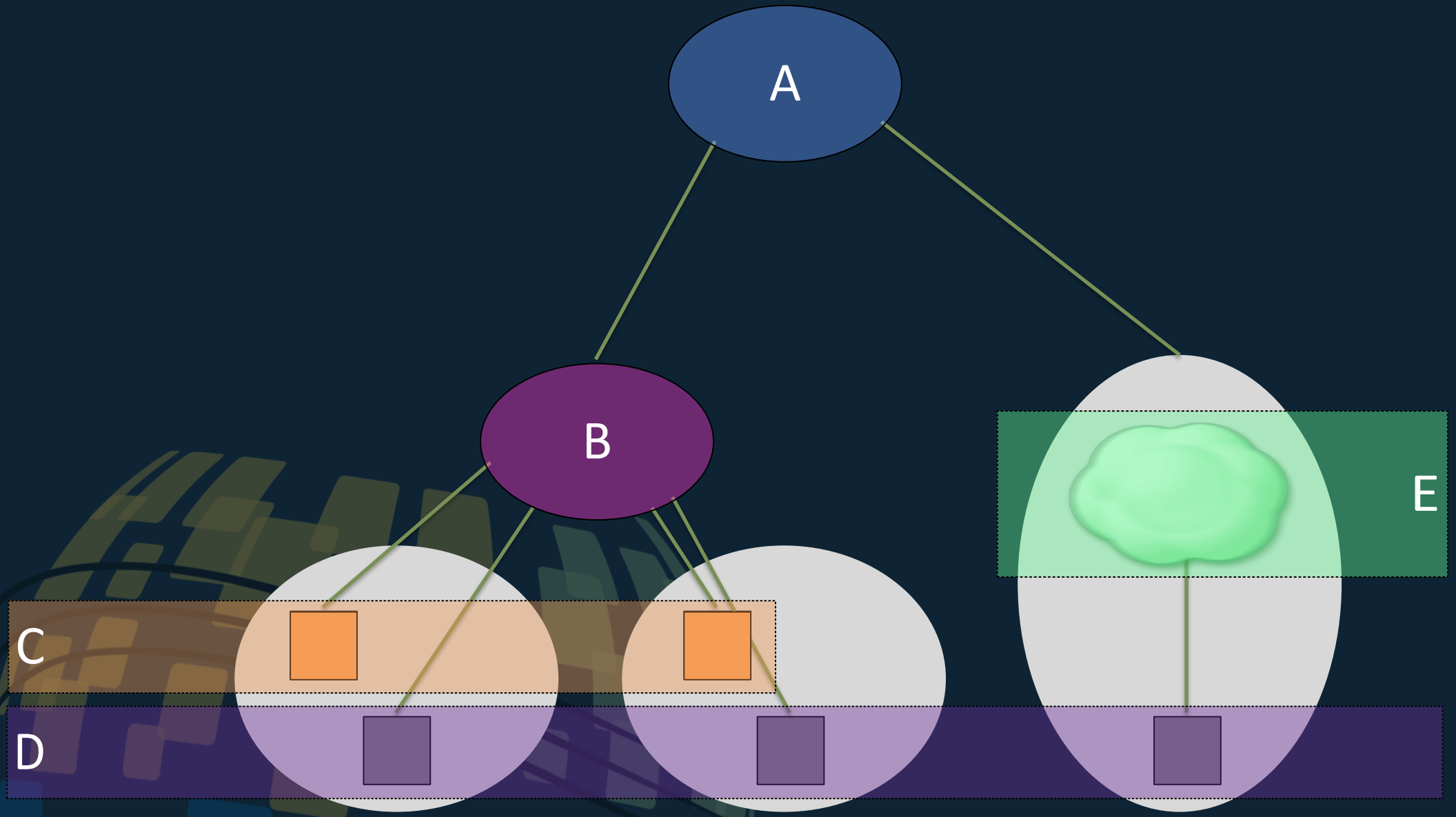
Node 3 Type Y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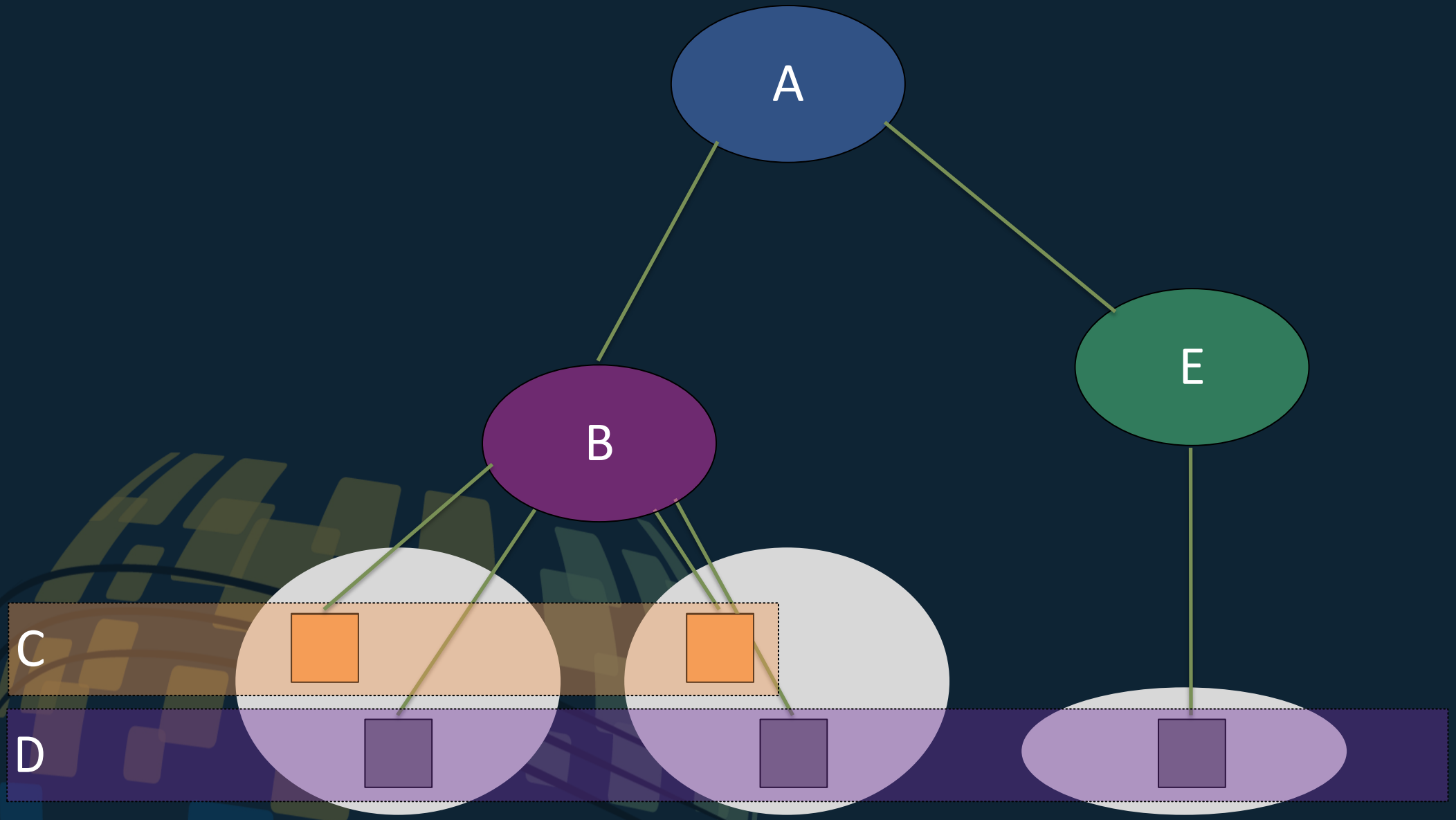
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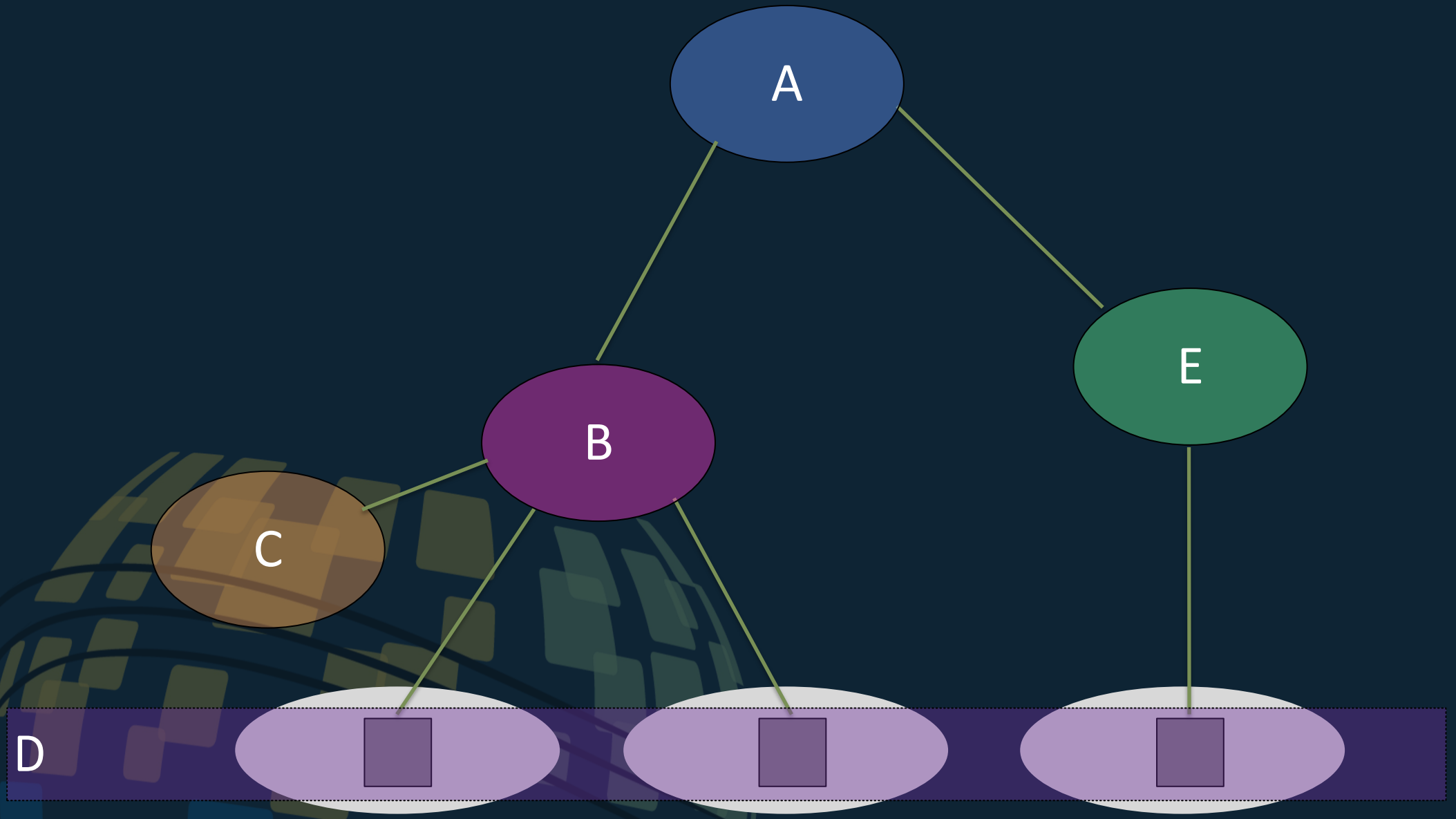
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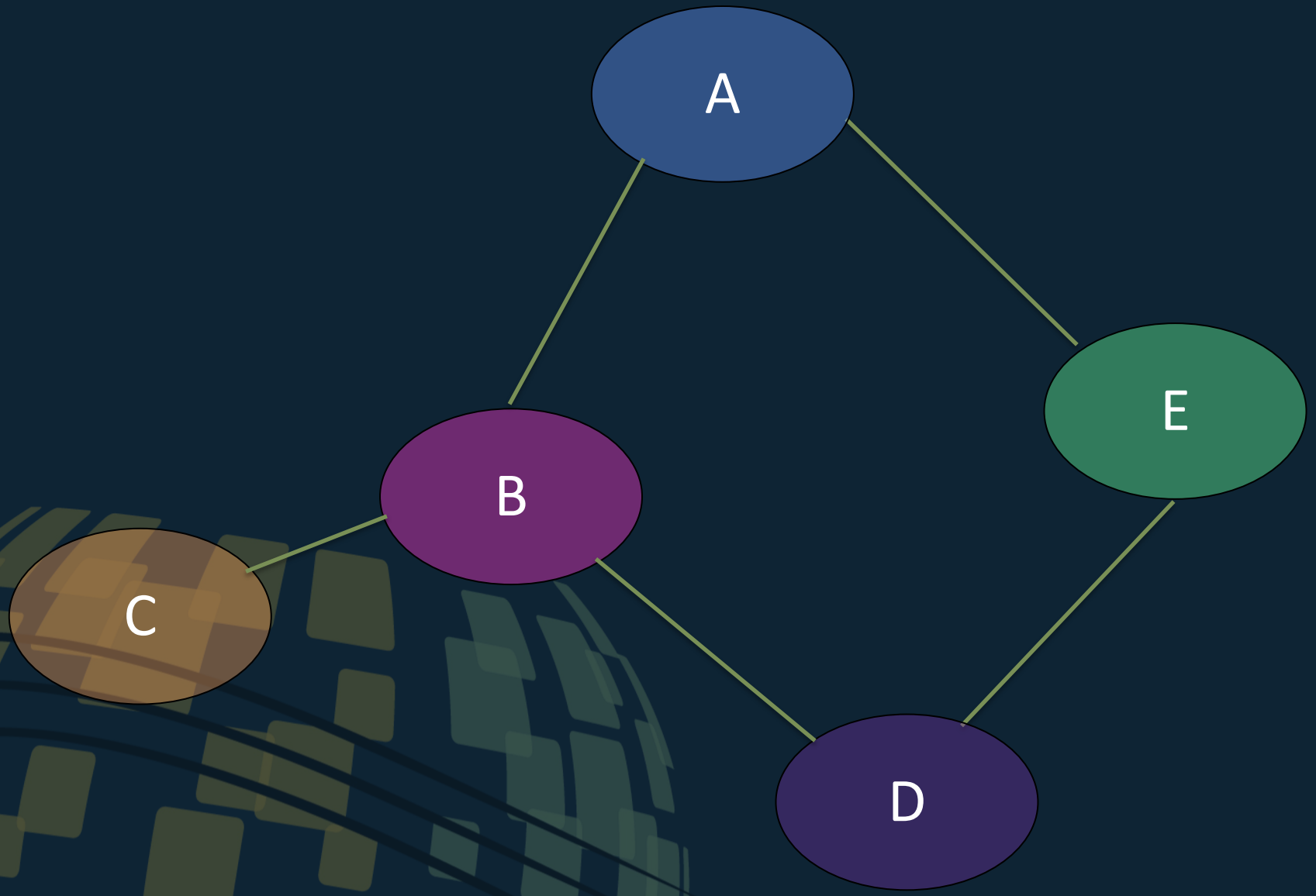
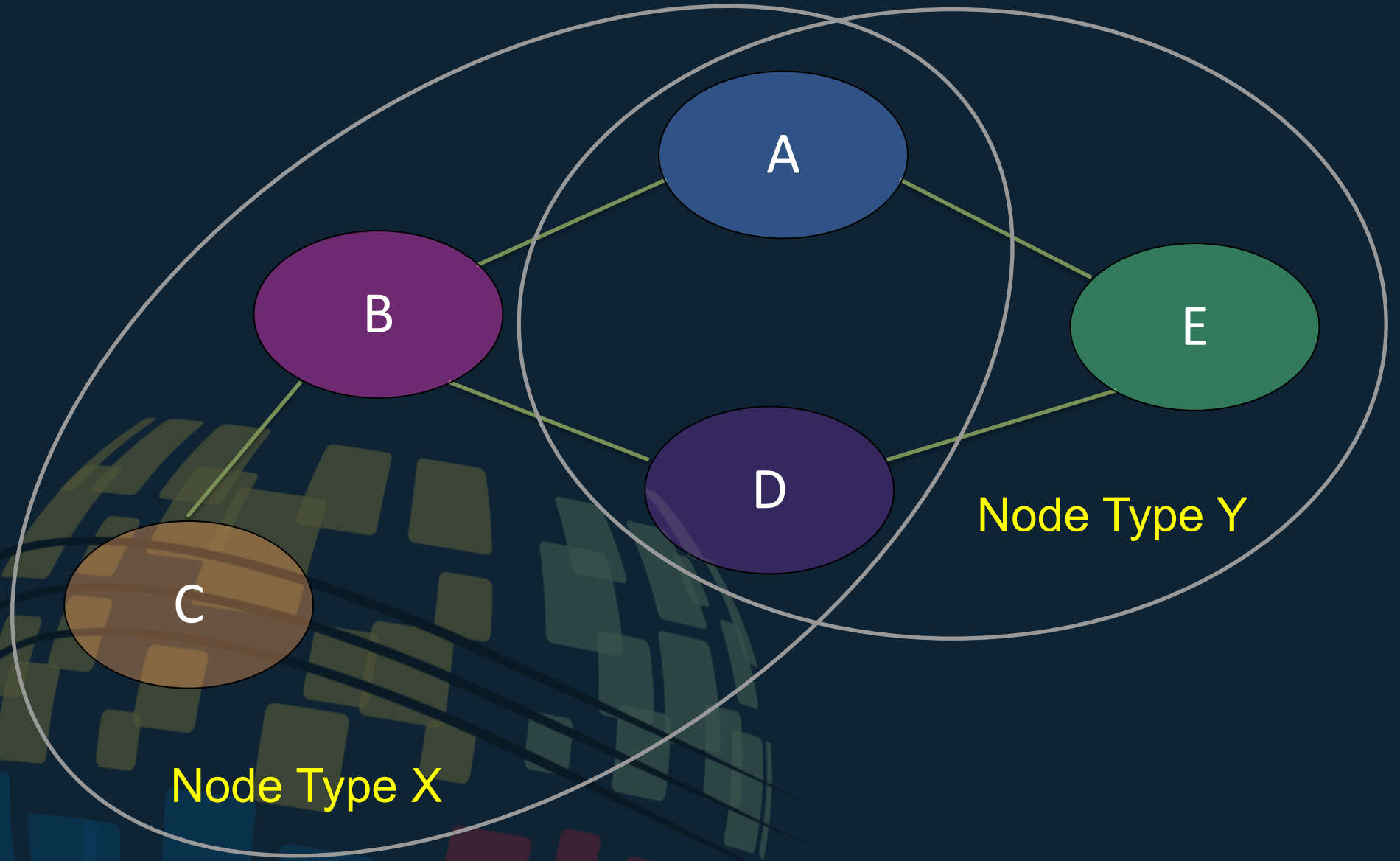
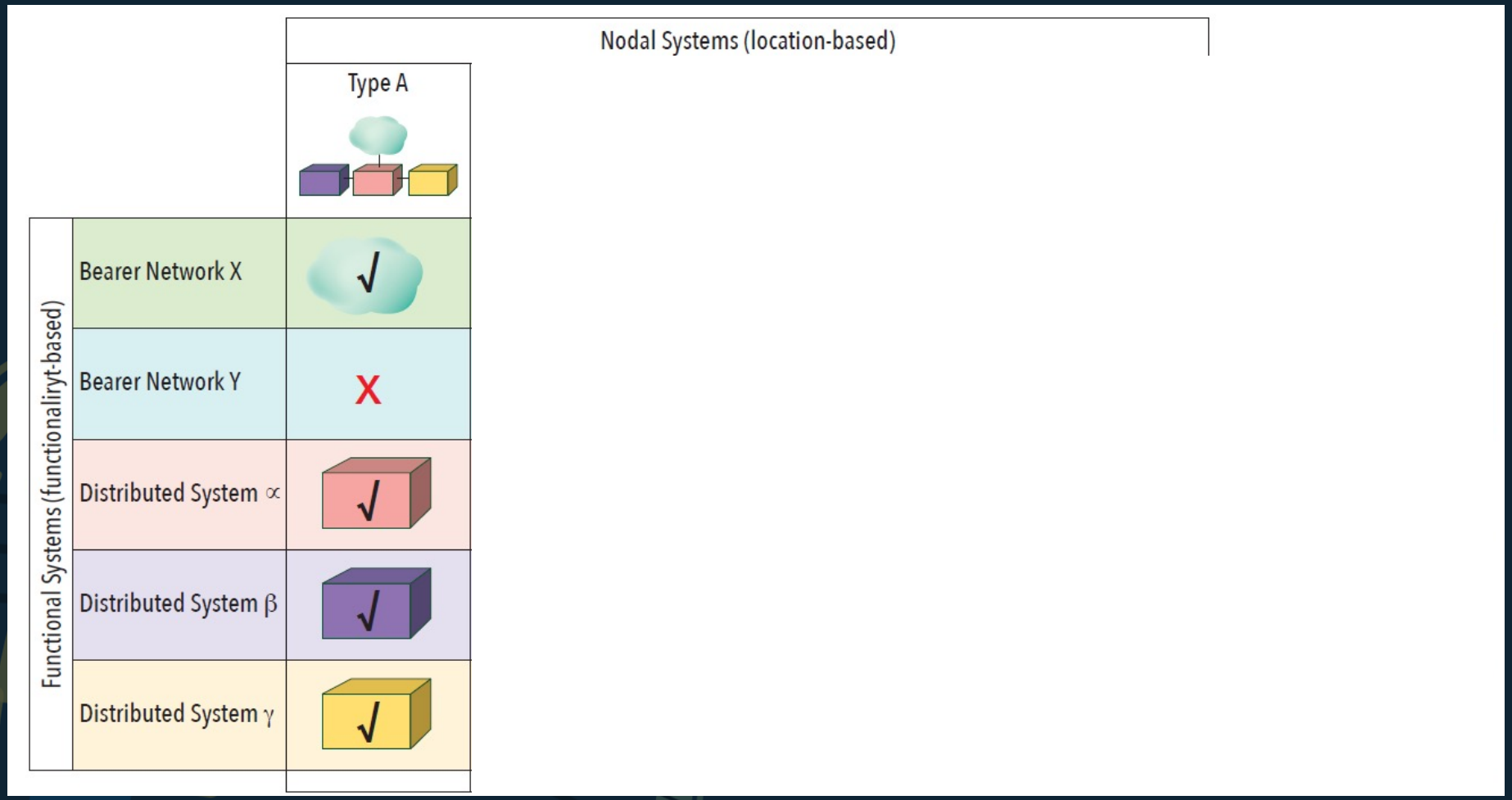
Node 2 Type X
Node 3 Type Y



Node 1 Type X Node 2 Type X Node 3 Type Y


A
B
C
D
E
Node Type X
Node Type Y

‘Fourier Transform’ for Networks:



Assessing Criticality

September 2020 - Holiday Farm Fire at the McKenzie River near Leaburg Dam. - ***Credit Holiday Farm Fire on Facebook***

Credit: Oregon Department of Transportation

ODOT camera shows fire destroying radio tower near Detroit.mp4

Halls Ridge Radio Site

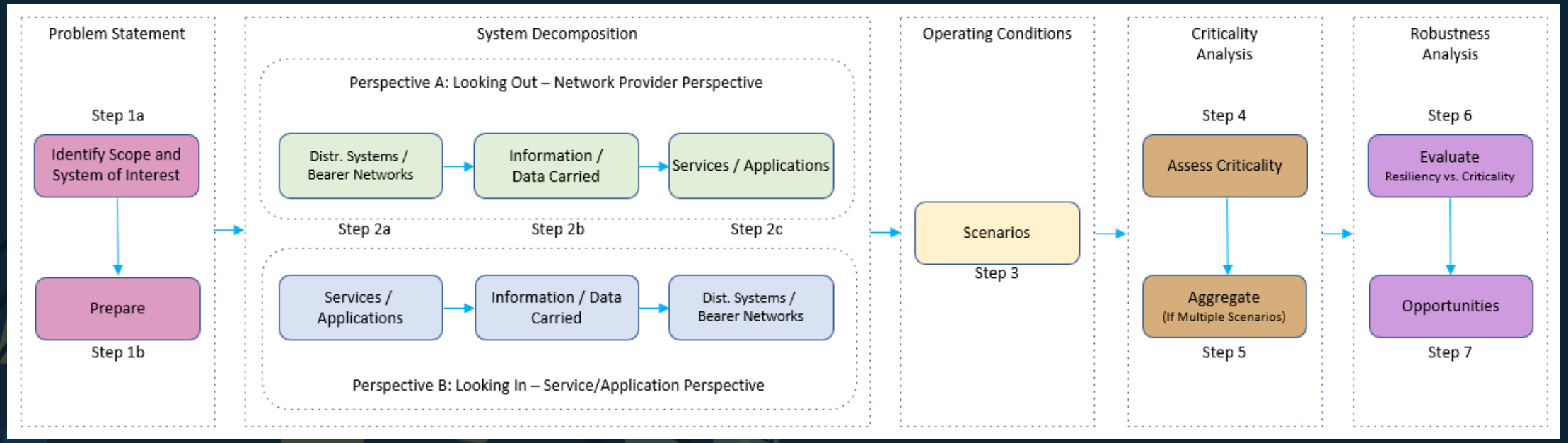
Detroit, Oregon

June 2020

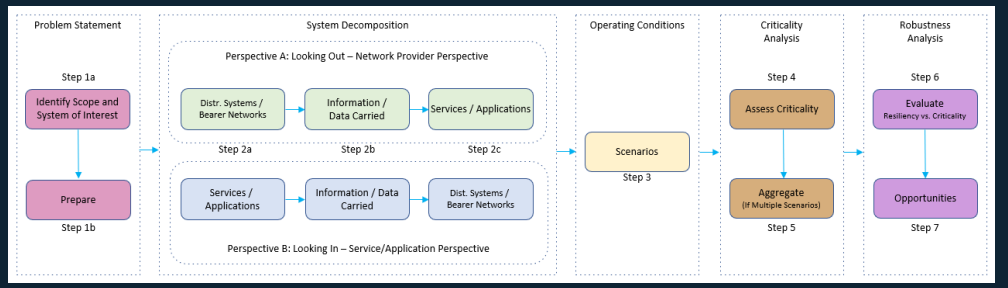
Credit: ADCOMM Engineering LLC

Criticality Framework

- Identity potential single points of failures
- Determine how and where best to expend funds



Criticality Framework



- Define Problem Statement
  - Identify Scope & System of Interest
  - Prepare for Assessment
- Decompose System – based on User Perspective
  - Stakeholder/ User: Services/ applications
  - Network Provider: Bearer network
- Define Operating Conditions
  - Identify potential scenarios, blue sky vs rainy day
- Assess Criticality
  - Identify potential single and aggregated failures
- Robustness Analysis
  - Determine where to make improvements/ investments

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