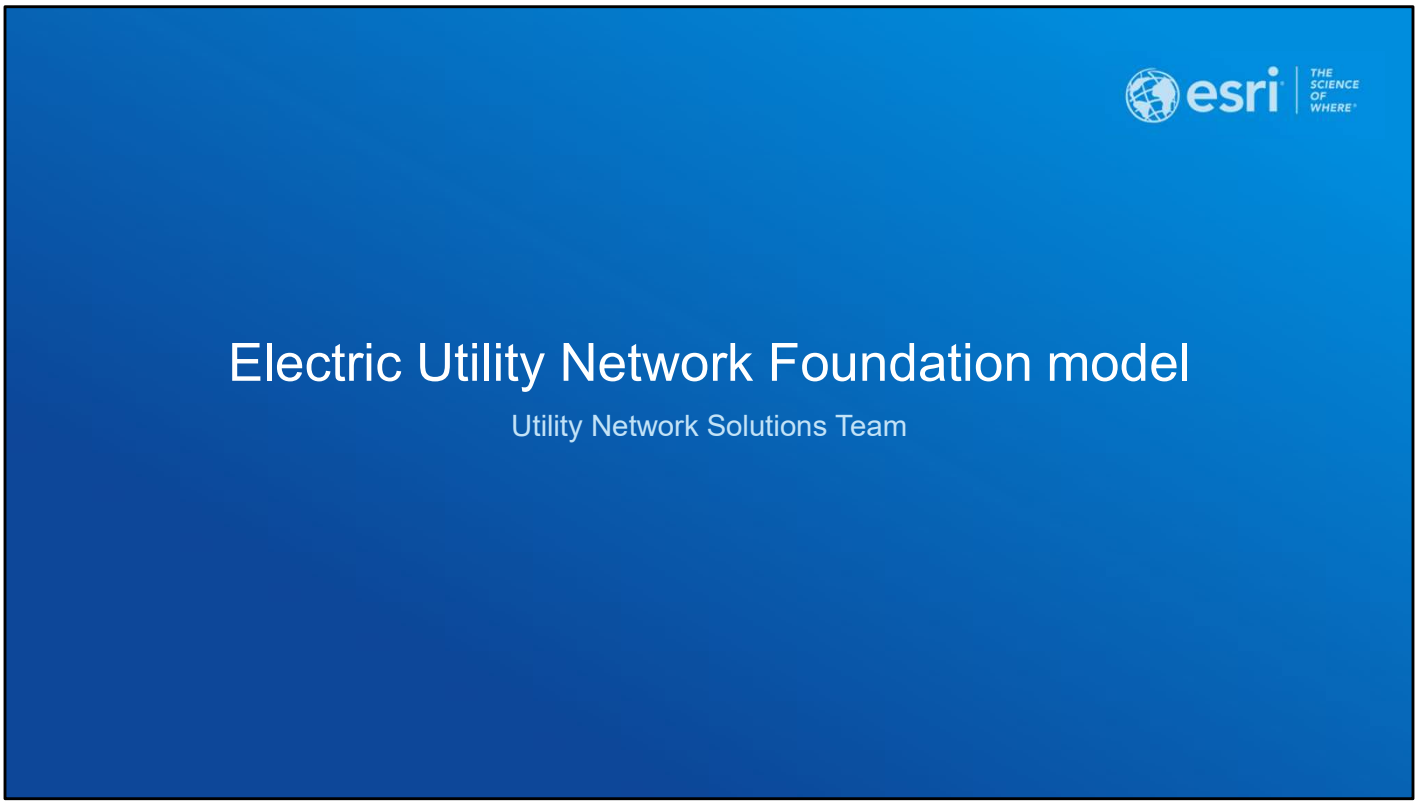


Esri Corporate Template-Dark v4.1
January 5, 2022

Key Utility Network concepts

This is the second presentation in our series on the Esri EUNF or Electric Utility Network Foundation. In this presentation we want to make sure we have a good understanding of how the Utility Network works, so we will review some of the key concepts of the Utility Network.

Key Utility Network concepts

- Barriers
- Network Categories
- Network Attributes
- Attribute Propagation
- Subnetwork Controllers
- Subnetwork

Just like having a common understanding about electricity, we need to have a common understanding of the Utility Network and it's terms and concepts. These are the key areas we will cover.

Barriers

What are they?

- Barrier – Conditions of features that stop a trace
- Types of Barriers
  - Feature - Geometry used to define location of barrier
  - Function – Simple Functions used to calculate a Stop Point or Barrier
  - Condition – Use to Network Attributes to Categories to determine the Stop Point or Barrier

Barriers are the end of the pipe or line for tracing. It is where the trace stops. There are several types of barriers that are used in the Utility Network

Barriers

Feature Barrier

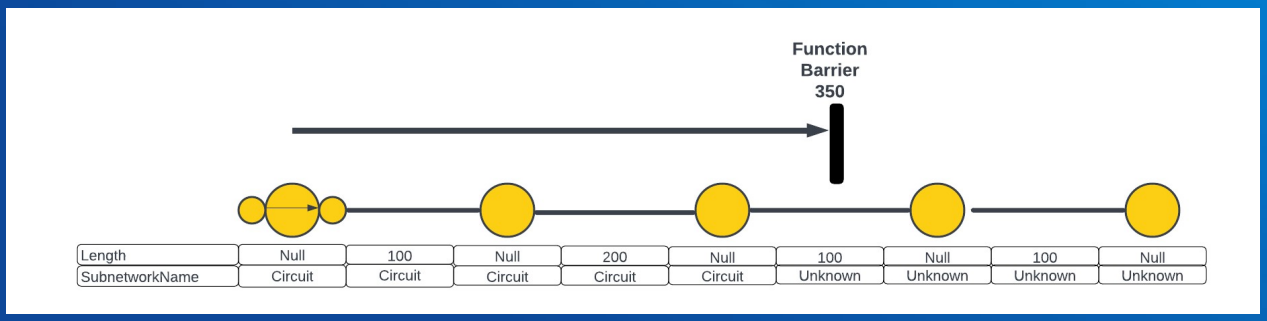
- These are barriers created from features and stored in the Barriers feature class.
- The Barrier feature class is not part of the Utility Network database schema
- Similar to Start Points, but spatially where the trace should not pass through

Feature Barriers are just that, features you place that are not features in the utility Network, but do act as barriers for tracing.

Barriers

What are they?

- Function – Uses simple mathematical functions that leverage network attributes to define location the barrier
  - Distance Trace, count

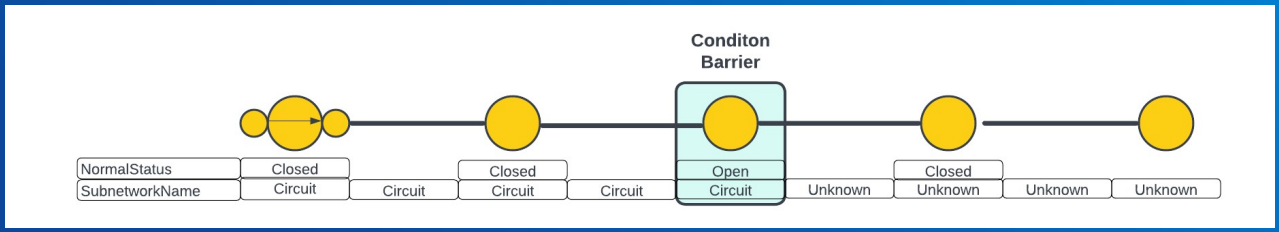


Function Barriers are pretty cool in that they can stop when some addition has been reached. Like Distance.
In this example, we are summing “Length” and we want to stop when it reaches 350 units.
You could also count the number of Protective devices, For example, I want to go upstream to the third protective device.

Barriers

What are they?

- Condition – Uses network attributes or categories to define the barrier



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Condition Barriers are where we use attribute values to determine if something is a barriers, like a switchable device being open. When the trace encounters a feature with this attribute set to Open, it will stop.

Network Categories

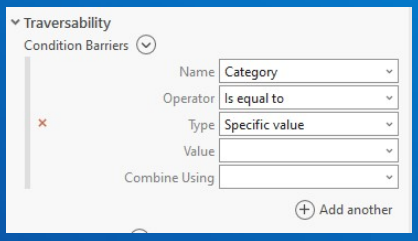
- Tags used to represent characteristics of an asset
- Assigned by Asset Type
- Can be assigned to multiple Asset Types in different asset groups in different utility network classes
- Can be used in Utility Network Traces instead of using multiple barriers by asset type

We have used network categories extensively in the EUNF model. Categories are assigned at the asset type level and have a performance advantage in tracing because of that.
Also, the same network category can be assigned to multiple asset types. So, if you want to look for a switchable device, you can assign the Switch network category to switches, fuses, reclosers, sectionalizer and circuit breakers. This make you trace easier to setup, as you don't have to look for each asset type.

Network Categories

How are they used in Traces?

- In Trace GP Tool, can be used in Traversability, Filters and Output, both in as a Barrier or Function Barrier



Also, the network categories can be used in multiple trace parameters.

Network Categories

Electric Model

- Total of 92 Categories
- Cable Type
- Switchable Device and capabilities
- Transformers
- Voltage Regulators
- PFC (Capacitors)

category_name	Asset Type Assignments
Wire Aerial Support Structure	30
Subnetwork Tap	10
Subnetwork Controller	119
Overhead Spans	3
E:Voltage Regulation - Junction Objects	1
E:Voltage Regulation - Device Features	20
E:Voltage Regulation - Assembly Features	20
E:Voltage Regulation	41
E:Transformer - Voltage - Junction Objects	53
E:Transformer - Voltage - Device Features	52
E:Transformer - Voltage - Assembly Features	28
E:Transformer - Voltage	133
E:Transformer - Step - Junction Objects	34
E:Transformer - Step - Device Features	29
E:Transformer - Step - Assembly Features	10
E:Transformer - Step	73
E:Transformer - Power - Junction Objects	12
E:Transformer - Power - Device Features	11
E:Transformer - Power	23
E:Transformer - Distribution - Junction Objects	12
E:Transformer - Distribution - Device Features	16
E:Transformer - Distribution - Assembly Features	14
E:Transformer - Distribution	42
E:Switch - Sectionalizing - Junction Objects	10
E:Switch - Sectionalizing - Device Features	14
E:Switch - Sectionalizing - Assembly Features	3
E:Switch - Sectionalizing	26
E:Switch - Section Devices - Junction Objects	175
E:Switch - Section Devices - Device Features	189
E:Switch - Section Devices	384
E:Switch - Reclosing - Junction Objects	26
E:Switch - Reclosing - Device Features	30
E:Switch - Reclosing - Assembly Features	3
E:Switch - Reclosing	59
E:Switch - Load Break - Junction Objects	77
E:Switch - Load Break - Device Features	74
E:Switch - Load Break - Assembly Features	13

We use a lot of network categories in the EUNF model. Here are the general categories

Network Categories

Transformers

- Transformer
  - Distribution
    - Provides the final voltage transformation in the electric power distribution system
  - Step
    - Increases the voltage from primary to secondary
  - Voltage
    - Changes the voltage
  - Power
    - Operates with high voltages and currents in the power system network

Some network categories specific to transformers

Network Categories

Switchable Devices

- Switchable Device and capabilities
  - Load Breaking
    - Can be opened under load conditions
  - Disconnect
    - Can be opened, but not under load conditions
  - Protective
    - Can interrupt an electric circuit in case a parameter exceeds a predetermined value
  - Circuit Breaker
    - can interrupt an electric circuit in case a parameter exceeds a predetermined value and is capable of automatic reclosing
  - Reclosing
    - capable of closing by automatic means after a time interval
  - Sectionalizing
    - Automatically isolates a faulting section

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Some additional net category groupings

Network Attributes

What are they?

- Network attributes are associated with attributes on objects in your network. They are derived from attributes and stored inside the network topology to aid in performance while feature attributes are evaluated during a trace.
- Data Types
  - Short
  - Long
  - Double
  - Date
- Storage
  - In-Line specifies whether the network attribute is persisted inline in the main network index
    - Better performance
    - Only supported for Short and Long data types

Another feature of the utility network is Network Attributes. These are attributes that can be used to control traversibility , like barriers.
Notice Text is not one of the supported data types.

Network Attributes

Storage

- Storage
  - Can be stored In-Line or Non In-Line with the network index
- Non In-Line
  - Faster than querying features, but slower than In-Line
- In-Line
  - Fastest query
  - Best used for attributes that are used as part of the subnetwork trace

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How Network Attributes are stored is very important and has impacts on performance, especially with larger systems
In-Line network attributes are the fastest, but have other limitations
Most Network Attributes will be stored as Non In-Line

Network Attributes

Available bits

- Bits shared between all domain network in a Utility Network
- Key attributes used in Update Subnetwork
  - Lifecycle Status - 3 bits
  - Device Status – 3 bits
  - Field Operation – 3 bits
  - Phase – 4 bit

ArcGIS Release	Bits
3.0 and above	25
2.9	21
2.8 and below	20

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In-Line is faster than Non In-Line, since they are stored with the main network index. However, there are limits as to how many bits can be stored this way, so use them sparingly!
We have four network attributes in the EUNF model. They use a total of 13 bits, leaving between 7 and 12 bits free.
If you add another domain network, like communications, these bits are shared with that domain network!

Network Attributes

Why use them?

- Can be used to control trace behavior
  - Only attributes that are network attributes can
    - Can be used in Summaries
    - Can be used in Condition Barriers
- Same network attribute can cross feature classes
  - These eases use in Export Subnetwork
- But at what cost?
  - Potential performance impact on inserts, updates and deletes, just like any index

Network Attributes can be used to control trace behaviors, and network attributes can be used in Summaries and Condition Barriers.
They do help with performance of trace, but can have an impact on editing. For example, when a network attribute is edited, it creates a dirty area.

Network Attributes

Lifecycle Status

- 4 bits used
- 4 key values
- Only In Service is part of Subnetwork Definition
- Any feature with a lifecycle status other than In Service is considered a barrier
  - Which means if you include barriers in the trace, these are returned by the trace

Code	Description
0	Out of Service
1	Proposed
2	In Service
4	Planned Removal

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Now, we will cover some specific network attributes that are stored In-Line.
The Lifecycle status is a bit gate, where each bit has a meaning
Also, we have harmonized the lifecycle status field and codes across all our industry models.

Network Attributes

Lifecycle Status Domain

- 7 valid values when bits combined
- Why no 5?
  - That would include only Proposed and Planned Removal, not In Service

Code	Description	Comments
0	Out of Service	
1	Proposed	
2	In Service	
3	Proposed and In Service	New facilities and existing
4	Planned Removal	
6	In Service & Planned Removal	Existing facilities and things to be taken out of service
7	Maintenance	This is everything

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The domain assigned to lifecycle status provides all the valid combinations

Network Attribute

Lifecycle Status

- Proposed and In Service Features
  - Examples
    - New Subdivision
- Maintenance
  - Second most common state to view
  - This would include Proposed, In Service and Planned Removal
    - Example
      - Road Widening

Lifecycle status is used to allow future facilities to be included in a trace.
For example, a new subdivision would be proposed features
You can also exclude features that are to be remove. For example, a road widening, which removes a lot of facilities and places new ones. Both can be stored in the utility network, but their traceability is controlled by lifecycle status

Network Attributes

Device Status

- Used to control traversability in the utility network subnetwork definition
- Three values

Code	Description	Notes
0	Closed	Trace passes through
1	Open	Trace stops inside this location
2	Open, Traceable	Allows for a trace that remove this condition barrier to deterministically assign the de-energized section to a circuit

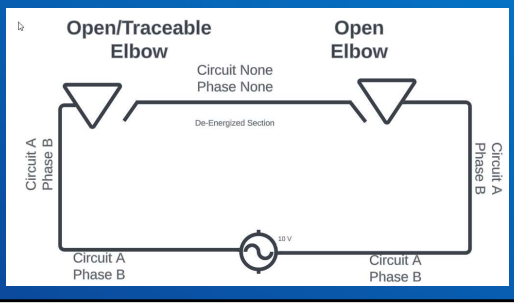
Open, Traceable will be discuss later

Device status is used in all switchable devices to control flow of power.
The domain we use contains three values, Open and Closed and a third state called Open, Traceable. This third state is used in cases where we want to include De-Energized equipment.
We will provide some examples of how to leverage these values in tracing in our tracing presentation.

Network Attributes

Device Status – Open, Traceable

- Why use this value?
  - Cases where you may have de-energized equipment that still needs to be part of a subnetwork
  - This allows for exporting to external system, such as ADMS or OMS
- How it is used
  - Subnetwork Definition defines it as a subnetwork barrier
  - Remove this Condition Barrier on Export Subnetwork to include the De-Energized section in the subnetwork



In cases where conductor or equipment could be de-energized, but you want to extract it to feed in to ADMS or OMS. Details of this will be covered in tracing

Network Attributes

Field Operation

- How is the Electrical Equipment operated?

Code3	Description	Notes
0	Unknown	No idea how it is operated or don't care
1	Gang Operated	All present phases are operated at the same time
2	Phase Operable	Can open individual phases independently of status of other phases
3	Gang and Phase Operable	Both Gang and Phase Operable

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We added a network attribute for indicating how a switchable device is operated, by phase or Gang operated. You may want to stop a trace at the first gang operable device.

Network Attributes

Phase

- Model supports a maximum of Three Phases
- Support Phase labeling differently for each Tier
  - High Voltage typically uses I,II,III
  - Medium Voltage typically uses ABC
  - Low Voltage typically uses abc
- Why different domains?
  - To signify that phase changes when it passes through a Transformer of similar equipment

Code	High Voltage	Medium Voltage	Low Voltage
0	De-Energized	De-Energized	De-Energized
1	III	C	c
2	II	B	b
4	I	A	a

We have modeled Three phases in our phase network attributes.

Network Attributes

Phase

- All combinations of Phase

Code	Bits	High Voltage	Medium Voltage	Low Voltage
0	000	De-energized	De-energized	De-energized
1	001	III	C	c
2	010	II	B	b
3	011	II,III	BC	bc
4	100	I	A	a
5	101	I,III	AC	ac
6	110	I,II	AB	ab
7	111	I,II,III	ABC	abc

This support single, two and three phase systems. We have used industry typical labels for voltage classes as there are no established standards.
We typically see I,II,III for high Voltage and ABC or RYB or RST or 123 for medium voltage and or L1,L2,L3 or abc for Low Voltage

Network Attributes

Phase

- Things Phase Network Attribute not used for
  - Phase Orientation
  - Phase Rotation
  - Phase Order

Please do no try to expand the phase domain to support Phase Orientation, that will not work and will actually cause problems. If you wish to track phase orientation, please use another attribute that is not a network attribute.

Network Attributes

Attribute Propagation

- What is it?
  - The ability to allow the system to manage an attribute related to the traversibility of the network
- Why do I need it?
  - To reduce user time spent to manage these attributes
  - Ensure accuracy of the attribute information that is impacted by traversibility
- What electric things can be propagated?
  - Phase
- Origin
  - Currently propagation starts from the Subnetwork Controller

Propagation currently only truly works with Phase. Many have asked about propagation of voltage, but since voltage can be stepped up or down, limitations in the current software do not support this use.
Propagation starts and the subnetwork controller and is pushed downstream from this point.

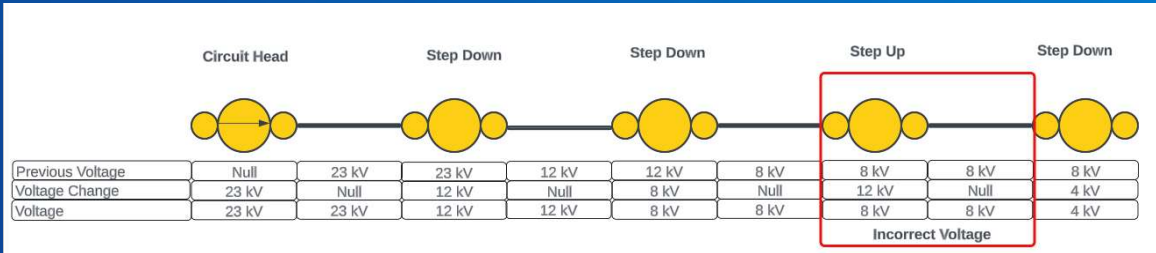
Attribute Propagation

- Derives objects attribute value from network attributes and traversability
- One of three functions can be used in a single propagator
  - Propagated_MIN
  - Propagated_MAX
  - Propagated_BITWISE_AND

Propagate Min

Propagating Minimum Value

- Propagated value from previous object is compared to the propagation change value, which ever is the least is set to the propagated value of the object



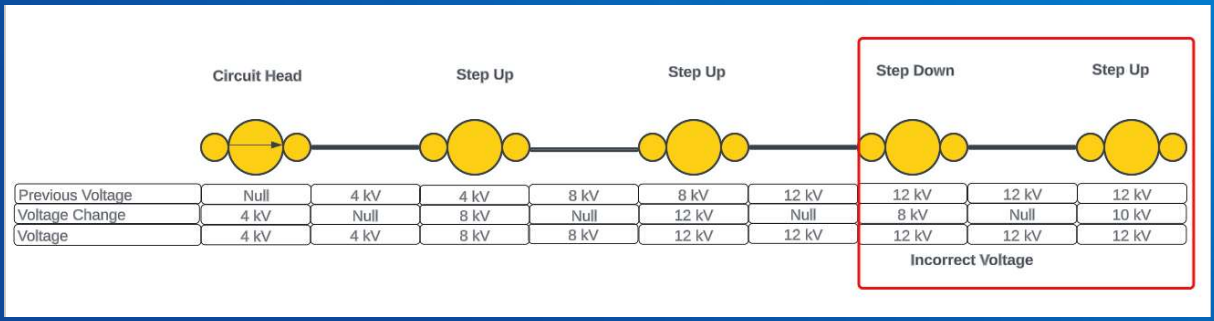
Previous Voltage	Null	23 kV	23 kV	12 kV	12 kV	8 kV	8 kV	8 kV	8 kV
Voltage Change	23 kV	Null	12 kV	Null	8 kV	Null	12 kV	Null	4 kV
Voltage	23 kV	23 kV	12 kV	12 kV	8 kV	8 kV	8 kV	8 kV	4 kV

Note, we do not use Propagation for Voltage in the Electric Model.

Propagate Max

Propagating Minimum Value

- Propagated value from previous object is compared to the propagation change value, which ever is the largest is set to the propagated value of the object



Previous Voltage	Null	4 kV	4 kV	8 kV	8 kV	12 kV	12 kV	12 kV	12 kV
Voltage Change	4 kV	Null	8 kV	Null	12 kV	Null	8 kV	Null	10 kV
Voltage	4 kV	4 kV	8 kV	8 kV	12 kV	12 kV	12 kV	12 kV	12 kV

As you saw from these two examples of voltage propagation, you can get the incorrect voltage propagated when you have a mix of Step Up and Step Down Transformers

Propagate BITWISE AND

Attributes

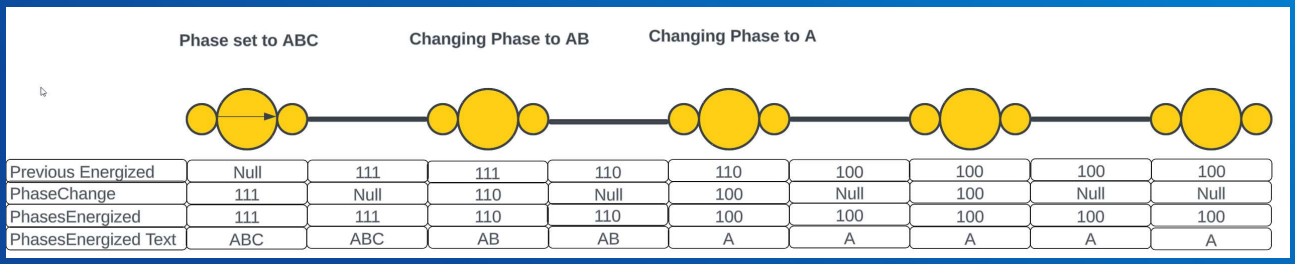
- Attributes used in Phase Propagation
  - Phase Change
    - Input of propagation
  - Phases Energized
    - Output of propagation

Bitwise And

- What is a BITWISE AND?
  - A bitwise operation operates on two-bit patterns of equal lengths by positionally matching their individual bits
  - Copies a bit to the result if it exists in both operands. The result is 1 only if both bits are 1

	Example 1	Example 2	Example 3	Example 4
Value 1	0	0	1	1
Value 2	0	1	0	1
Result	0	0	0	1

Phase Propagation



Previous Energized	Null	111	111	110	110	100	100	100	100
PhaseChange	111	Null	110	Null	100	Null	100	Null	Null
PhasesEnergized	111	111	110	110	100	100	100	100	100
PhasesEnergized Text	ABC	ABC	AB	AB	A	A	A	A	A

PhasesEnergized from previous object is and'd with PhaseChange of the current object to calculate the new Phases Energized value

Subnetworks

What is a subnetwork

- Esri Definition
  - A subnetwork represents a topological subset in a tier where all participating features have traversability to the same subnetwork controllers.
- Is A Subnetwork = Circuit?
  - Kind of, but not really
- Circuit or Feeder
  - A complete route electric current can flow around
  - Can start anywhere you wish, but typically at Circuit Breakers, Reclosers, Switches, Fuses or Transformers

Is a subnetwork a Circuit, well kind of, but not necessarily. We will go deeper in to Subnetworks

Subnetworks

Purpose

- Assign a Name based on traversability, attachment or containment
  - SubnetworkName
  - SupportedSubnetworkName
  - SupportingSubnetworkName
- Propagate a value based on traversability and other network rules and definitions
- Allow the use of summaries for things like counts
- Ensure only allowed equipment is part of the subnetwork

Subnetworks are for assigning names to a group of features and to propagate the phase to ensure that features are assigned correct phasing.

Subnetwork Controllers

- Required for subnetwork management
- Some Domain Device or JunctionObject that acts as the start of the subnetwork
- Terminal Configuration used must have at least two terminals
- Terminal Configuration must be directional
- Must have Network Category of Subnetwork Controller

This is a key concept for Utility Networks. Only Devices and JunctionObjects can act as subnetwork controllers.
They must have a terminal configuration and since our domain network is partitioned, the terminal definition must be directional with at least one upstream terminal