The bridge to possible

Distributed Automation Solution Brief

Direct Transfer Trip Over Cellular

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Direct Transfer Trip (DTT) Over Cellular for Distributed Energy Resources (DER) Sites

Introduction

Wireless technologies offer an alternate solution to using wired topologies enabling communications for several distribution grid use cases. Wireless technology is especially useful in providing connectivity to Distributed Energy Resources (DER) assets and the local distribution substations.

Typically, protection equipment will operate locally, and does not require data from other devices to do so. Some schemes do use communications for normal operations. One such scheme is Direct Transfer Trip (DTT) in which upstream substations must trip DER assets off the network in the event the substation feeder breaker opens.

Traditionally, Direct Transfer Trip Signals (DTT) sent between substations and remote Distributed Generation (DG) sites using leased telephone lines were used. DTT systems are installed for critical high-speed tripping of circuit breakers on either side of a feeder interconnecting substations or between the substation breaker and a DG equipment site station.

Cisco Validation Solution

Cisco undertook work to validate the use of cellular networks to provide a flexible and easy-to-deploy connectivity solution to provide the backhaul technology. Today, cellular networks are reliable and low cost to deploy compared to dedicated fiber.

The focus of this solution is on leveraging standards-based and scalable communication technologies to provide encrypted connectivity between sites while supporting the transport of layer 2 multicast non-routable IEC61850 GOOSE messaging in secure peer-to-peer topologies. The same solution will natively allow SCADA data also to be transported within the same encrypted tunnels.

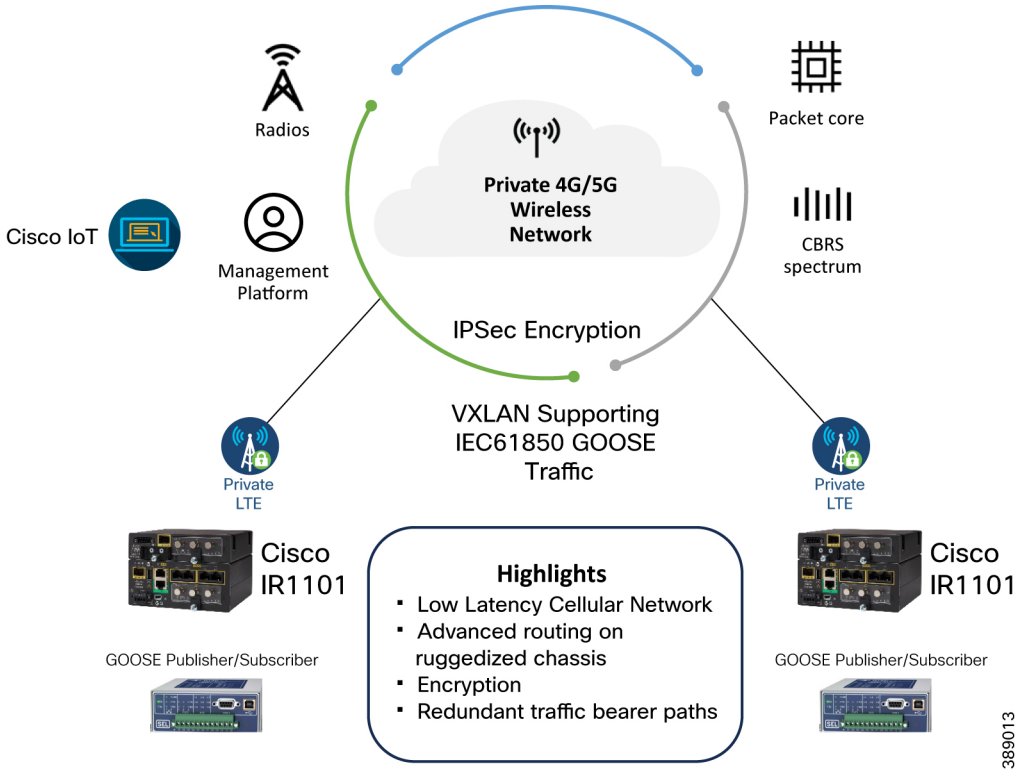
It was important to evaluate the latency, jitter, and packet loss applicable to these private and commercial cellular networks when applied to the DTT use cases.

Primary timing design focus of the validation follow:

- IEEE 1547-2018 states for DTT operation DER assets should be disconnected within 2 seconds to prevent ‘islanding’ scenarios. Note: The communications timing budget within this is much less.
- Customer requirements for the actual communication timing budget typically range from 40ms to 80ms.

This solution shown in Figure 1 uses the Catalyst IR1101 rugged router used widely in distributed automation networks today with plugin cellular modules to support the various commercial and private spectrum bands, including: CBRS, Anterix, and commercial bands (such as Firstnet).

Figure 1. Architecture for DTT use case



Deployment to Existing Cisco IR1101 platforms

DTT is another use case that could be deployed on existing Cisco IR1101 platforms. Adding the DTT use case can be done centrally via templated configuration on the Cisco Field Network Director management platform. This provides an optional capability that can be provisioned into the network where required.

This solution guide describes the following DTT use cases:

- Encrypted tunnels providing secure transport of SCADA traffic from Distribution Automation network locations to the Utility Control Center (for example, DNP3 IP based SCADA traffic).
- Encrypted tunnels providing secure transport of IEC61850 GOOSE traffic between DER sites and upstream recloser controllers or substation devices.
- In band segregated network to allow remote management of the grid devices, such as reclosers.

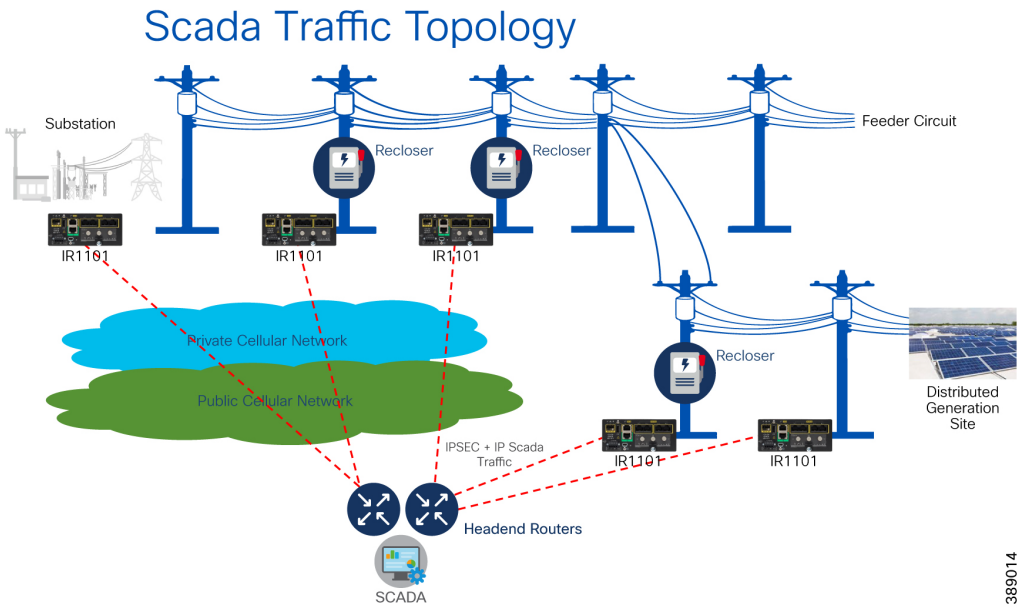
SCADA

In a SCADA scenario, the following apply:

- The Cisco Catalyst IR1101 acts as the secure edge device. Connected via cellular and using IPsec tunnels (Cisco FlexVPN) to secure the data plane.
- The Cisco IR1101 can be deployed within recloser cabinets in the field or at distribution substations and at the DER site.
- The IPSEC tunnels provide a hub and spoke topology between all sites and the headends at the utility data centers.

Figure 2 shows the topology for using SCADA on existing IR1101 platforms.

Figure 2. SCADA use case Architecture



Direct Transfer Trip

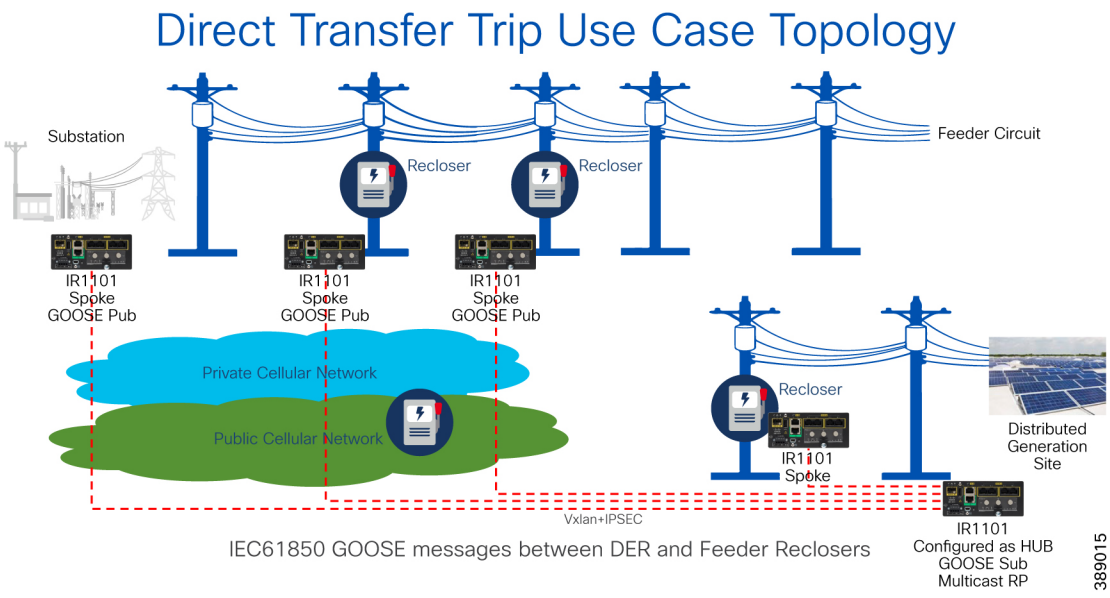
Leveraging the same underlying infrastructure to enable this additional use case. VXLAN is classed as a virtual ‘overlay’ network which runs on top of the underlying network. This provides a segregated virtual network to transport layer 2 traffic from one point to another. Using a VXLAN overlay with separate IPSEC tunnels to secure transport of the IEC61850 GOOSE traffic between relevant grid or DER devices.

This small overlay also operates in a minimum Hub-and-Spoke topology, providing simple configuration and templated parameters that can be pushed from the Cisco DA management platform, the Field Network Director.

The DER site acts as a mini hub device for multiple upstream reclosers to publish their GOOSE messages. The DER site can subscribe to the published GOOSE streams and take appropriate actions when necessary to protect the DER site and prevent islanding.

Figure 3 shows the topology for DTT.

Figure 3. DTT use case Architecture



Recloser Management

This validated design also provides an in-band segregated network, Management VRF, that allows the reclosers to be managed remotely. Staff can access and configure the recloser controllers from remote locations. All access is secured via the underlying IPSEC tunnels and segregated from critical SCADA traffic.

Management of the end reclosers can normally be achieved by two mechanisms: serial port and in-band via the ethernet port.

This validated design provides a solution to both methods:

- Recloser controller serial ports connecting to the Catalyst IR1101 serial port
- That serial port then transports the serial data via the Raw Sockets protocol to a central point, where it is re-constituted back to a serial port connection or connected into a virtual serial port terminal server.

For the in-band ethernet based connection, traffic is transported to the control center via the secure IPSEC tunnels, where an engineer can access the management session using any engineer workstation.

Direct Transfer Trip Summary

Traditionally, Direct Transfer Trip Signals (DTT) were sent between substations and remote Distributed Generation (DG) sites using leased telephone lines. DTT systems are installed for critical high-speed tripping of circuit breakers on either side of a feeder, interconnecting substations or between the substation breaker and DG site station equipment.

Key points for this DTT use case are:

- DER site monitors upstream reclosers for a trip signal
- DER site disconnects itself from the grid when receiving the required trip signal
- Cisco Catalyst IR1101 rugged router with required Cisco cellular plugin modules are used to allow flexibility on the selected cellular module.
- Standards based VXLAN used to transport the layer 2 multicast GOOSE messages
- IPSEC/IKEv2 tunnels used for security between all endpoints
- Scalability required for more complex topologies
- Security, IPsec for WAN-side encryption and the Catalyst IR1101 Rugged router also supports MACsec on the LAN ports with SEL 651R reclosers
- A single management platform providing zero-touch provisioning via templates of all the configuration options using Cisco Field Network Director.

Cisco Validated Solution

The Cisco validated design provides a single platform for delivering all three use cases. They are not all mandatory and can be delivered when required in addition to the base SCADA use case. The Catalyst IR1101 rugged router can be used for additional use cases.

This design has validated all three uses with SEL 651R recloser controllers in a setup typical of a Direct Transfer Trip solution for DER anti-islanding scenario.

Some key points of the solution are:

- DER site subscribes to upstream reclosers for IEC61850 GOOSE messages.
- DER site disconnects itself from the grid when appropriate signals are received.
- Cisco Catalyst IR1101 platform is used with various cellular plug-in modules available covering Private and Public 4 and 5G bands.
- The solution leverages VXLAN technology to transport layer 2 GOOSE messages over a secured layer 3 network between sites (IPSEC over cellular). This is more scalable that traditional point-to-point tunnelling methods to transport layer 2 traffic, such as L2TPv3.
- IPSEC tunnels are used for security between endpoints. Cisco FlexVPN technology is leveraged which includes IKEv2 and 'smart defaults' on the Catalyst IR1101 to ease configuration.
- Simple and complex topologies:
  - Point-to-point layer 2 GOOSE
  - Point-to-multipoint layer 2 GOOSE
- Redundant traffic bearer paths (multiple cellular connections)
- Scalability (larger groups of routers acting as layer 2 endpoints)
- Security is mandatory for all WAN connections (IPSEC encryption) and MACSEC is available to secure the local connection from the IR1101 to the recloser controller.
- IEEE 1547-2018 states for DTT operation disconnect DER <2 sec.
- SEL 651 Recloser and 3505 RTAC commonly deployed for this type of use case and are used in the validated solution.

Layer 2 Network Transport

Traditionally L2TPv3 was the go-to protocol to tunnel any type of layer 2 traffic over a layer 3 network. It was commonly used for transporting IEC61850 GOOSE traffic between substations over a layer 3 IP network.

L2TPv3 also introduces some disadvantages listed here:

- Scalability – Being a point-to-point tunnel it does not scale when larger numbers of devices are required. Each device connection requires a single tunnel, and this leads to more complex configurations with multiple tunnels to manage on each router.
- Multicast – L2TPv3 by default does not support Multicast natively.
- Configuration – L2TPv3 does not support any form of virtual segregation, each service that needs segregation requires the use of a separate tunnel.

For this solution Cisco chose to leverage the VXLAN capabilities available on the Catalyst IR1101 rugged router.

VXLAN is a MAC in IP/UDP (MAC-in-UDP) encapsulation technique with a 24-bit segment identifier in the form of a VXLAN ID. The larger VXLAN ID allows LAN segments to scale to 16 million in a network.

In addition, the IP/UDP encapsulation allows each LAN segment to be extended across existing Layer 3 networks, making use of Layer 3 Equal-Cost Multi-Path (ECMP).

Avantages of VXLAN :

- Scalability - VXLAN extends the L2 Segment ID field to 24 bits, which potentially allows up to 16 million unique L2 segments over the same network.
- L2 Segment Elasticity over L3 Boundary - VXLAN encapsulates an L2 frame in an IP-UDP header, allowing L2 adjacency across router boundaries.
- Leverages multicast in the transport network to simulate flooding behavior for broadcast, unknown unicast, and multicast in the L2 segment.
- Leverages Equal-Cost Multi-Pathing (ECMP) to achieve optimal path usage over the transport network.

Conclusions

This new solution provides a validated design to address the increasingly-complex distribution network requirements proposed from integrating renewable energy assets.

The Cisco catalyst IR1101 rugged router provides a platform to deliver the flexibility to add these new complex services to existing deployments and provide security out of the box.

Cellular DTT uses cases that are viable and have been tested by various research organizations. Cellular provides an easier and lower cost method to deploy anti-islanding to remote DER assets.

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