Pertanika J. Sci. & Technol. 25 (S): 25 - 38 (2017)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

# Opportunity for Using WLAN with IEC 61850 and the Future of this Protocol

**N. H. Ali[1]*, Borhanuddin. M. Ali[1], O. Basir[1], M. L. Othman[2], F. Hashim[1] and E. Aker[2]**

[1]*Department of Computer and Communication Systems Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia*
[2]*Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia*

## ABSTRACT

The unified protocols are unified in application interface, models, and seamless. They generate one standard protocol, one world called IEC 61850. IEC 61850 integrate the security, interoperability, modelling, mapping to a substation, and reliability. Presently, the more expensive fiber based Ethernet LAN is the most prevalent technology for medium and low voltage distribution substations. To circumvent this problem Wireless Local Area Network (WLAN) has been investigated for its suitability for applications that are compliant to IEC 61850: automation and metering; control and monitoring; and over-current protection. In this paper the IEEE 802.11n WLAN is studied when used in various IEC 61850 supported applications for substation automation. It also discusses the benefits of using GOOSE message to protect and control applications and the use of IEC 61850.

*Keywords:* IEC 61850, GOOSE, WLAN, Smart Grid

ARTICLE INFO

*Article history:*
Received: 24 August 2016
Accepted: 02 December 2016

*E-mail addresses:*
nasir200420022000@yahoo.ca (N. H. Ali),
borhan@upm.edu.my (Borhanuddin, M. Ali),
obasir@uwaterloo.ca (O. Basi),
lutfi@upm.edu.my (M. L. Othman),
fazirulhisyam.hashim@gmail.com (F. Hashim),
hadi.aker@yahoo.com (E. Aker)
*Corresponding Author

ISSN: 0128-7680 

## INTRODUCTION

Control and Protection engineers are often faced with many problems that can be stated with alternative easy inquiry “To IEC 61850 or Not to IEC 61850”. The answers regarding too many engineering works in control and automation in the substations is obviously yes. IEC61850 protocol is the only one that supports systems based on multi-vendor Intelligent Electronic Devices (IEDs) networked together to provide protection, monitoring, automation, metering, and control functions. The interoperability of equipment and systems is ensured by providing compatibility between interfaces, protocols, and data models.

This paper presents stations implementing this new IEC 61580 standard and applications examples which are organized for them. The IEC 61850 standard applicability and viability as the recognized communication standard for substations automation are excellent. Therefore, it is possible with IEC 61580-GOOSE to achieve high speed communication for interlocking switchgears across bays (substations). The 'generic object-oriented substation event' is abbreviated as GOOSE, a service of fast communication that is independent of the communication between the client (centralized station controller) and the server (bay control unit). The WLAN is being widely organized in smart networks (Parikh et al., 2010). The WLAN was studied extensively for home automations and industrial applications due to its simplicity (Gungor et al., 2010). A few examples of research in WLAN for control, monitoring and protection have been described in (Ali et al., 2015). Numerous automation systems which use WLAN has defined in (Parikh et al., 2013) and the application of the same Wireless Local Area Network (WLAN) in substations was done as well (Abdel-Latif et al., 2009). In the above-mentioned articles, performances of wireless LAN have been evaluated for the applications of IEC 61850 based smart network supply substation. They classify possible applications of smart distribution and show that the WLAN technology can achieve technical and economic advantages in these applications. In this paper, we focus on the presentation of the ETE Delay of GOOSE message using the multipoint to point (Access Point) network. The influence of Radio Frequency Interference (RFI), and Electro-Magnetic Interference (EMI) effect, was assumed to be the Gaussian probability density function distribution. The rest of this paper is organized as follows: after this section; focuses on the GOOSE message for IEC 61850, and section 3 describes the Future for IEC 61850. Finally, the conclusion is given in section 4.

## GOOSE MESSAGE FOR IEC 61850

Using the goose message in control and protection application will improve the reliability, performance, and efficiency of the system. The Transmission Control Protocol (TCP) is a connection-oriented protocol, the devices at the end points establish an end-to-end connection before any data is sent. TCP protocol is more reliable, because they guarantee that data will arrive in the proper sequence. Regarding to their principles TCP cannot meet the protection application requirements. This has led to another type of communication based on a connectionless technique. Using this technique of communication between Intelligent Electronic Devices (IEDs) means there is no assurance that the data will be received. Due to that IEC 61850 protocol has presented specific mechanisms to ensure the transfer of data to the receivers.

Peer-to-peer (P2P) communication standard used for IEC 61850 makes the control and protection very attractive. P2P communications in IEC 61850 can used unicast, or multicast for data delivery, enabling the IEDs to manage and exchange of information with all devices. In order to obtain high-speed control and protection in Substation Automation Systems (SASs), the system must meet specific requirements. The performance transfer time requirements needed for control, protection, monitoring, and recording are different based on IEC 61850.

Regarding to the definition of time transfer, the GOOSE communication is much better than hardware interface communication. Priority tagging improves the performance of protection, while the availability of VLAN improves the security and flooded the network.

Protection and control based on P2P communication in compliance with IEC 61850 was designed by the way that can meet the different requirements. The concept of event model not according to commands, but based on sending an indication that particular event is happening. This way will be support high speed and reliable communication between different IEDs and enabling to replace the hardwire signal between devices by using message exchange, as a result, the protection and automation control improved. The GOOSE communication messages based on a publisher/subscriber techniques. The publisher multicast GOOSE message to the different subscriber-servers or clients. As mentioned the GOOSE message replace the hard-wired signal in IEC 61850 When it is used for protection and control, then the GOOSE message introduces a different way that ensure the received information. It used the repetition techniques with varying time interval between the recurrent message until a new variation happening. The GOOSE messages recurrent with a growing time from Tmin to Tmax. The reiteration with Tmax continues forever, until the next event happens and the recurrent rate start again with Tmin see Figure 1. The GOOSE message having data attributes likes the sequence number (sqNum) and state number (stNum) which can be used for obtrusion finding. Then using GOOSE message for protection and control in substation automation system will reduce the installation cost; improve the reliability, overcoming the limitations of binary interfaces, and reduce maintenance.

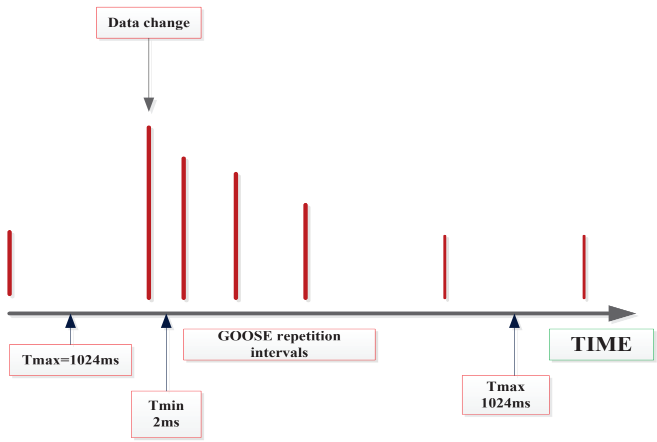


*Figure 1*. Reliability of the GOOSE messages

## MULTICAST GOOSE MESSAGE BENIFIT FOR FEEDER PROTECTION

Referring to Figure 2, the voltage drops when a fault occurs in feeder 2 in a distribution system results in an inrush condition after the clearing of the fault, this may lead to the undesired operation of protection elements of multifunctional relays on the healthy feeders. Once a fault on the feeder 2 that it is protecting is detected by a protection feeder IED, a GOOSE message will be sent to all other protection feeder IEDs telling them to guess an inrush as a result of the voltage recovery following the fault clearing.

Each of the protection feeder IEDs on the healthy feeders subscribes to GOOSE messages from all adjacent feeder protection IEDs and when it receives a message indicating adjacent feeder fault, it adapts its settings for the period of time that the expected inrush condition is going to last. This scenario was done as shown in Figure 2 using WLAN IEEE 802.11n with packet length 100 bytes for GOOSE message, and the fault feeder sends GOOSE message with repetition as shown in Figure 3, while the health feeder sends the GOOSE message as shown in Figure 4.

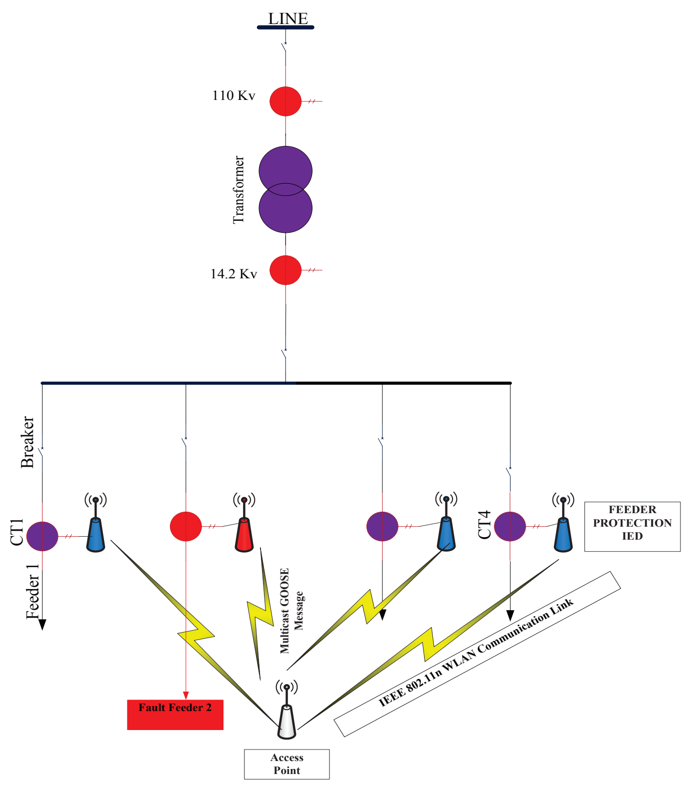


*Figure 2*. GOOSE message for fault feeder’s distribution

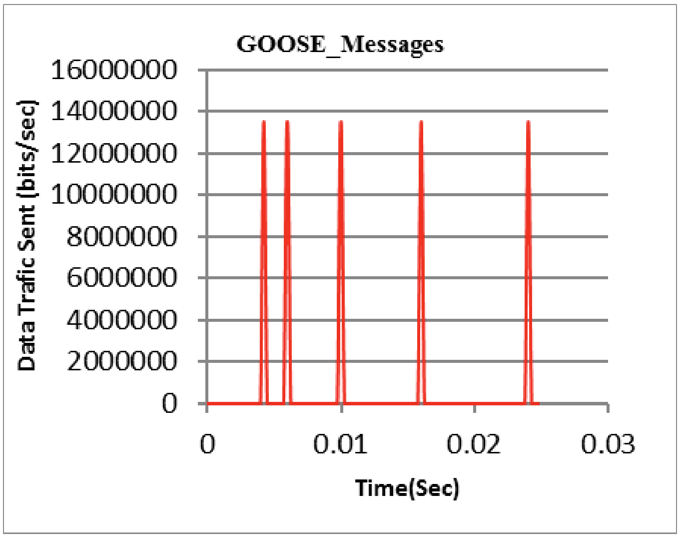


*Figure 3*. GOOSE message from Fault Feeders

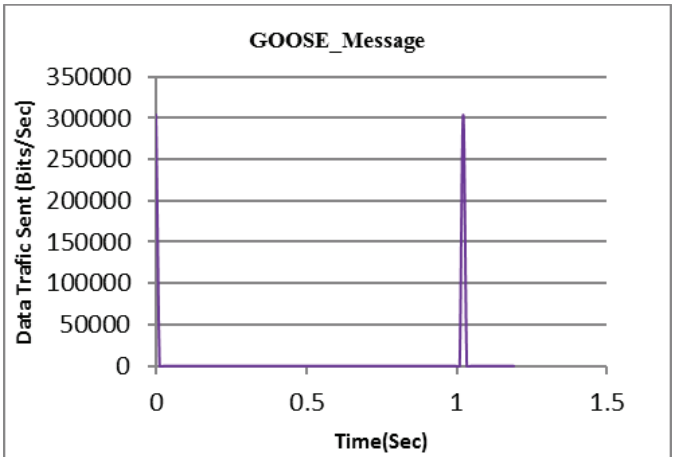


*Figure 4*. GOOSE message from Health Feeders

The ETE delay performance of this scenario at different path streaming and different signal to noise ratio was mentioned in Table 1. From Table 1 we can see that the ETE delay using WLAN Technology achieve the time delay requirements mentioned in IEC 61850-5. Except the case when the signal to noise ratio equal 19dB. In this scenario only require publishing and subscribing to GOOSE messages from the adjacent protection feeders' IEDs. Table 2 represent the same result at 5.0 GHz band of IEEE 802.11n, from Table 2 we can observe that delay is less compared to 2.4 GHz, but distance for 5.0 GHz is less.

Table 1
*ETE performance for IEEE 802.11n at 2.4 GHz Band*

| (S/N) signal to Noise ratio (dB) | Stream | Minimum ETE delay (ms) | Maximum ETE delay (ms) |
|---|---|---|---|
| 36.5 | 1 | 0.2 | 0.65 |
| 29 | 1 | 0.2 | 0.65 |
| 19 | 1 | 10 | 20 |
| 22 | 4 | 0.05 | 0.15 |

Table 2
*ETE performance for IEEE 802.11n at 5.0 GHz Band*

| (S/N) signal to Noise ratio (dB) | Stream | Minimum ETE delay (ms) | Maximum ETE delay (ms) |
|---|---|---|---|
| 33 | 4 | 0.055 | 0.085 |
| 33 | 1 | 0.070 | 0.090 |
| 22 | 1 | 0.090 | 0.095 |
| 22 | 4 | 0.06 | 0.09 |

## CENTRALIZED LOAD SHEDDING USING WLAN GOOSE MESSAGE.

Allocated load shedding is a new idea, in which, every individual allocation feeder to be prepared with an IED which could accomplish the function of load shedding and calculate the frequency. That means also every feeder relays requires having a voltage input that generally specifies a higher cost device of high end. Nevertheless, this kind of a device not only offers protection, but recording, measurements and other required functions also, and improved consistency of the system of load shedding.

While in centralized load shedding a single relay in the substation acts as one step of the scheme of load shedding and performs measurement of frequency at one point in the substation. When more than one step is required, extra under-frequency relays would be used.

Centralized systems of load shedding have also been used nowadays in the microprocessor based relays world. However, voltage relay and specified frequency could be used to do the functions of complex load shedding in several steps and according to different standards as specified by the plan of defence. The breakers tripping could be completed using GOOSE messages. The group of loads that need to be shed would be determined by the device of load-shedding, starting generally with lower priority loads. When using GOOSE messages, the network would receive a message suggesting which step has operated and the distribution feeder IEDs subscribing to this message would tumble their related breakers. Referring to Figure 5 the centralized shedding was implemented based on wireless LAN for three feeders communicate with centralized shedding IED using GOOSE message, the feeders send the load status each 50ms with packet length 100 bytes and each feeder having a different priority. The centralized load IED received the GOOSE message from feeders, and take voltage reading and with advanced calculation if there is any instability in the frequency it will be send GOOSE message to trip minimum priority feeder. This simulation can be seen in Table 3 at different signal to noise ratio. The ETE delay achieved the requirement mention in IEC 61850-5. Table 4 shows the performance of WLAN at 5.0 GHz. The ETE delay at 5.0 GHz is less than at 2.4 GHz but it is more sensitive to the noise and distance between different nodes. The attribute parameter for this scenario used 100 bytes packet length, the feeder send status each 20 ms and the load shedding IED send a packet at rate 50 ms. This result was obtained using opnet 18.0 license simulators.

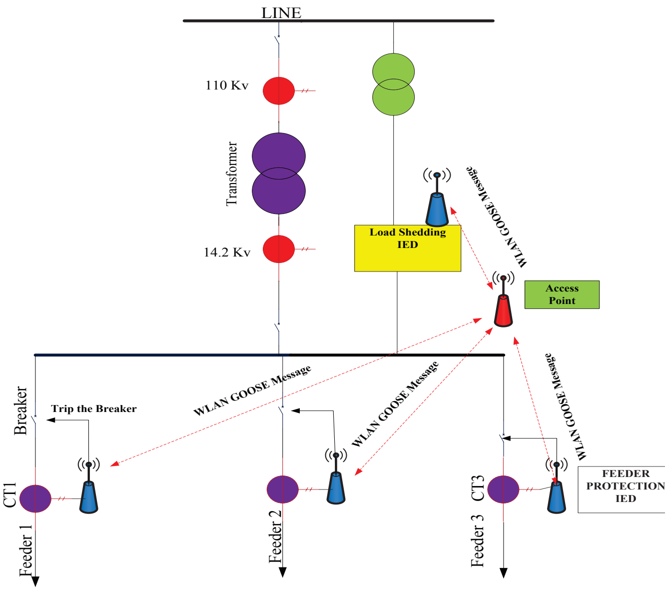


*Figure 5.* Centralized shedding based on wireless LAN

Table 3
*ETE performance for IEEE 802.11n at 2.4 GHz Band*

| (S/N) Signal to Noise ratio in (dB) | stream | Minimum ETE delay (ms) | Maximum ETE delay (ms) |
|---|---|---|---|
| 20 | 4 | 0.1 | 1.1 |
| 35 | 4 | 0.05 | 0.7 |
| 36 | 1 | 0.07 | 1.0 |
| 24 | 1 | 0.08 | 1.3 |
| 18 | 1 | 0.2 | 3 |

Table 4
*ETE performance for IEEE 802.11n at 5.0 GHz Band*

| (S/N) Signal to Noise ratio in (dB) | stream | Minimum ETE delay (ms) | Maximum ETE delay (ms) |
|---|---|---|---|
| 23 | 1 | 0.4 | 0.9 |
| 23 | 4 | 0.35 | 0.8 |
| 32 | 4 | 0.05 | 0.5 |
| 32 | 1 | 0.05 | 0.35 |
| 18 | 1 | 0.25 | 1.7 |

## FAST DISTRIBUTION BUS PROTECTION SCHEME

Using overcurrent relays is the normal way for protecting distribution bus. Usually, downstream feeder IEDs delays the upstream protection IED (IED-1) via coordination interval, i.e. approximately 400-500 ms or more. In the case of a fault in feeder, this coordination interval is injected to let downstream feeder IED before bus IED. Nevertheless, if there is a fault on bus, overcurrent protection of the bus would be delayed by this coordination delay (400 ms to 500 ms). Hence, delay could be extremely decreased via installing WLAN communication of a low cost as clarified below:

In this structure, peer-to-peer IEC 61850 GOOSE message could be used for signal sending from feeder protection IEDs to bus overcurrent IED. This structure needs only non-directional elements of overcurrent protective, with communication channel of a low cost (i.e. wireless LAN). In case of feeder fault, a fault would be detected by two IEDs: first, corresponding feeder IED, and second upstream bus IED. Thus, BLOCK command will immediately be sent by feeder IED using IEC 61850 GOOSE message, and the fault will be isolated by feeder IED. Furthermore, if the distribution substation bus has a fault, none of the feeder IEDs would detect the fault, and thus, no BLOCK message will be received by bus IED, and bus IED will be normally operated after an approximate delay of 60 ms. Therefore, coordination delay could be decreased from 400-500 ms down to 60 ms. The life of components installed on upstream of distribution bus will be improved by this structure, i.e. distribution transformer, as the fault current time going over these components lessens. See Figure 6. The ETE delay of GOOSE Block message can be seen in Figure 7. This delay increased as a signal to noise ratio decrease. This result was obtained when WLAN IEEE 802.11n work under single stream, and 400 ns Guard Interval, the fault feeder send GOOSE message at 1,000 Hz rate and packet length equal 100 bytes, while health feeder send GOOSE message at rate 1 sec.

## FUTURE WITH IEC 61850

IEC 61850 was originally designed based on the assumption that the bandwidth of the communication network will not be a limiting factor. For LANs with transmission speeds of 100 Mbit/s or greater, this assumption holds true in most cases. But for SS-to-SS communication,

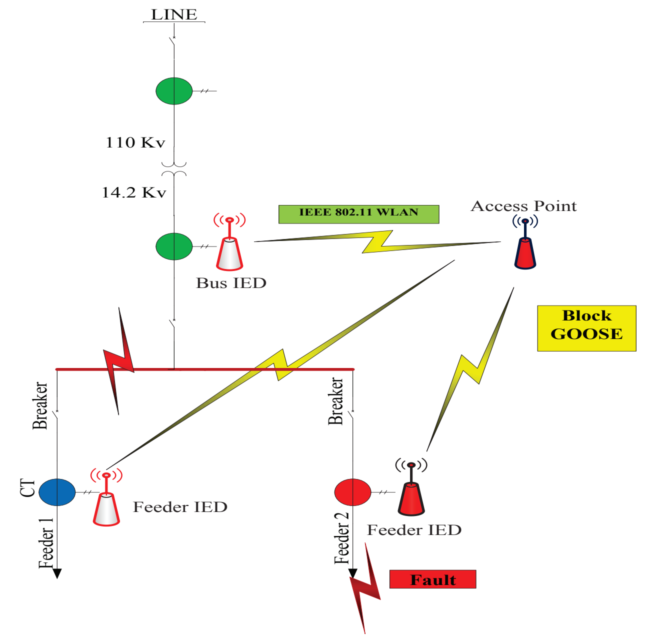


*Figure 6.* The concept of the fast distribution bus protection scheme

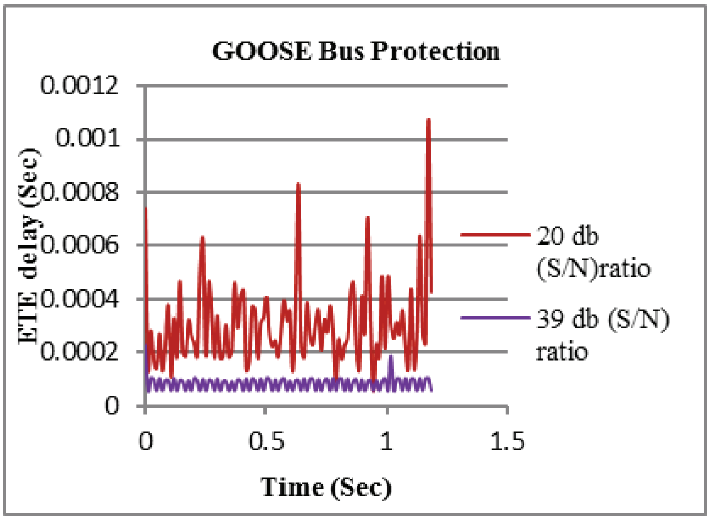


*Figure 7.* ETE GOOSE Message for Fast Bus protection

such communication paths generally does not exist requiring bandwidth limits be taken into account.

Apart from possible performance issues, the function D2 in station D shall be able to access function E2 in station E as if both would reside in the same local substation network.

There are two methods for that tunnelling approach and gateway approach as mentioned in IEC 61850-90-1. See Figure 8.

The operations of communication between SS-CC are described regarding to the different use situations. In this domain three main groups of users can be known. Distribution system operators (DSO), industrial power system operators and Transport system operators (TSO). Their conditions on the SS-CC communication are very different. There are two ways for communication between SS-CC to access the IEDs in the substation, first, using direct communication or using proxy/gateway as shown in Figure 9.

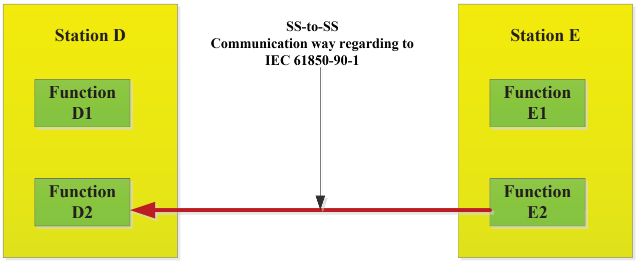


*Figure 8.* Substation to substation communication

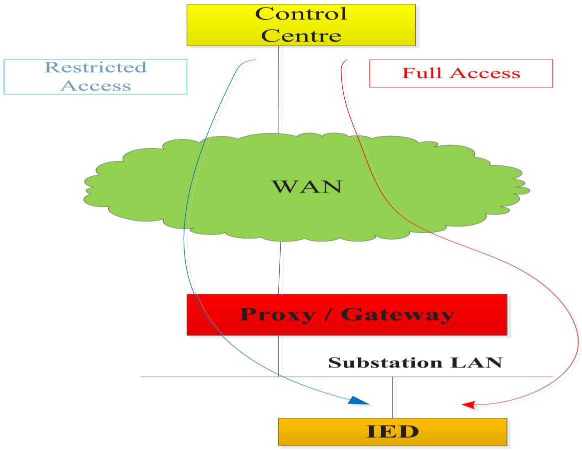


*Figure 9.* Proxy/gateway concept

## FULL ACCESS

Full access functions control Centre access the IEDs directly without pass through proxy/ gateway. This allows performing the same operations with the device as if it would be connected to the same network. Cyber security must be afforded for the connection to fulfil the security demands. "Tunnelling" is a way to join multiple communication networks. Using tunnelling as a communication link the substation network it becomes as a part of control centre network. The control centre can address the devices in substation network directly. Tunnel will be known by switch and routers in the network. The router can be connected to two independent communication path infrastructures to achieve redundancy. This way will provide communication path failure protection. Parallel redundancy for communication failure protection fit the demands of the industrial power system and other applications. For example, the remote services of IEDs (Figure 10).

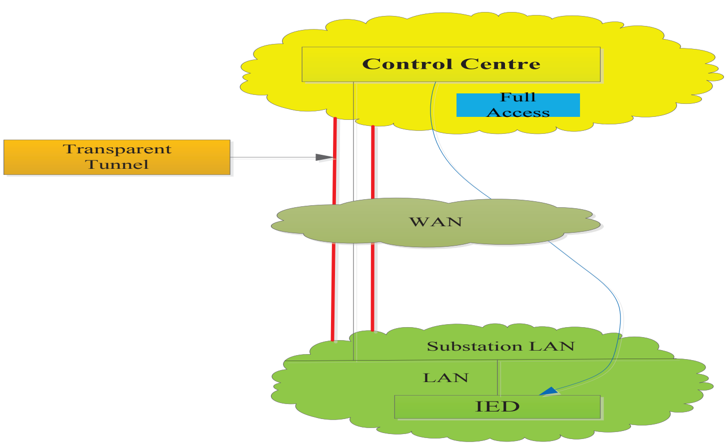


*Figure 10.* Full access to IED

## RESTRICTED ACCESS

The restricted access is used for different applications, and not limited to, SCADA applications. Restricted access application means that there is no direct access the devices. Presented data and services by proxy/gateway only can be used by those devices. The proxy idea has been part of the IEC61850 protocols standard from the beginning. It defines devices that present one by one copy of logical devices from other IEDs to a client. The proxy/gateway has been extended for the function of the SS-CC communications to enables the renaming and rearrangement of information.  This enables condensing and filters substation data. Furthermore, renames the data to switch from device oriented addressing to topological addressing. Then proxy/gateway access method improve the security because only those device data and services which are accessible from the outside that are configured in the proxy/gateway. IEC62351 is used for the SS-CC link to provide cyber security.

IEC 61850 Growth dramatically and will be used in Hydro power (IEC 61850-7-410), Distributed energy resources (IEC 61850-7-420), wind power (IEC 61400-25), Gate way mapping to IEC 60870-5-101/104 (IEC 61850-80-1), Between substations (IEC 61850-90-1), Between substation and control Centre (IEC 61850-90-2), GOOSE and Process Bus over IP Multicast for Synchrophasor communication (IEC 61850-90-5), and new mapping for IEC 61850 for using in the smart grid or web services. To integrate DER with IEC 61850 over Extensible Messaging and Presence Protocol (XMPP), The IEC 61850 specifies a method of exchanging non-time-critical data through any kinds of network, including public networks, using IEC 61850-8-2 Specific communication service mapping (SCSM) – Mapping to Extensible Messaging Presence Protocol (XMPP). The IEC 61850-8-2 is complementary to the existing SCSM (8-1); not competing sees Figure 11, and Figure 12 for more details.


*Figure 11.* Specific communication service mapping- Mapping to Extensible Messaging Presence Protocol

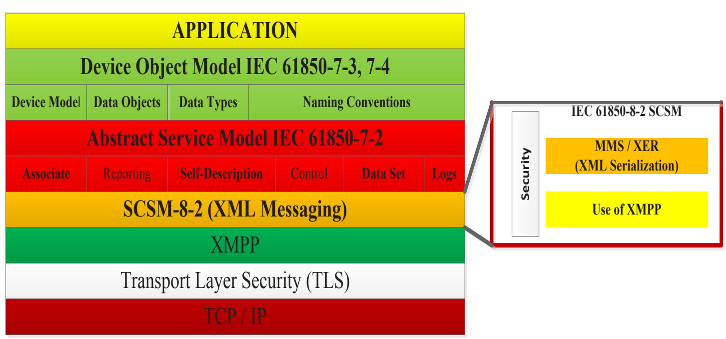


*Figure 12.* Protocol Stack for IEC 61850-8-2

## CONCLUSION

The GOOSE model lets the protection development, as well as the development of control systems, that give some important advantages comparing to conventional hard-wired systems. The GOOSE benefit includes reduced installation costs, improved flexibility, improved interoperability, reliability and performance, reduced maintenance. IEC 61850 substation architectures provide significant benefits to users and flexibility to accomplish new objectives that are too costly with legacy technology. Justification is challenging but realistic. IEC 61850-

8-2 extents the IEC 61850 technology by a mapping based on XMPP. It provides a secure and powerful communication for public networks considering end-to-middle and end-to-end security relations, IEC 61850-8-2 is intended to use for power management and demand response of DER (distributed energy resources).

## REFERNCES

Abdel-Latif, K. M., Eissa, M. M., Ali, A. S., Malik, O. P., & Masoud, M. E. (2009). Laboratory investigation of using Wi-Fi protocol for transmission line differential protection. *IEEE Transactions on Power Delivery, 2*4(3), 1087-1094.

Ali, N. H., Ali, B. B. M., Basir, O., Othman, M. L., & Hashim, F. B. (2015, December). WLAN oriented optimization of process bus in IEC 61850-based substation communication network. In *3rd International Renewable and Sustainable Energy Conference (IRSEC)* (pp. 1-6). IEEE.

Gungor, V. C., Lu, B., & Hancke, G. P. (2010). Opportunities and challenges of wireless sensor networks in smart grid. *IEEE transactions on Industrial Electronics, 57*(10), 3557-3564.

Parikh, P. P., Kanabar, M. G., & Sidhu, T. S. (2010, July). Opportunities and challenges of wireless communication technologies for smart grid applications. In *IEEE PES General Meeting* (pp. 1-7). IEEE.

Parikh, P. P., Sidhu, T. S., & Shami, A. (2013). A comprehensive investigation of wireless LAN for IEC 61850–based smart distribution substation applications. *IEEE Transactions on Industrial Informatics, 9*(3), 1466-1476.