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Cloud Computing Support for Smart Grid Applications

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Abstract: *The smart world requires a smart supply. The realization of a smart power system through cloud computing technologies is one of the trending innovations today. The smart systems provide interactive user interface in order to communicate. The communication through advanced metering systems and wireless communications has paved a way for implementation. The reliable, efficient, greener power supply can be expected as a result of implementation. The two way communication enables the consumer to introspect his power consumption through smart meters and information tools. This can also be used to inject excessive power that is being generated by localized power sectors through micro-grids. The rerouting and communication plays an important role in transmission, distribution and utilization cycle of the power system for which the platform like cloud computing is required. This paper discusses about the evolutionary approach of Cloud computing for the development of smart grid.*

Keyword: *Advanced Metering Infrastructure, Cloud Computing, Data Centers, Intelligent Monitoring System), Smart Grid, Wireless Communication.*

1. INTRODUCTION

Our current electric grid was conceived more than 100 years ago around 1890's, when the electricity needs where simple. The term grid basically refers to the electrical grid, a network of transmission lines, substations, transformers that fed electrical power from large central generators, transformers to a high voltage interconnected network that delivers electricity from the power plant to home or businesses. Earlier power generation was localized and built around communities. Most homes had only small energy demands such as a few light bulbs and a radio. The grid was designed for utilities to deliver electricity to the consumer's homes and bill them once or twice a month. Today it has 9200 electric generating units, more than one million MW of generating capacity connected to more than 300,000 miles of transmission lines. This one way interaction made it difficult for the grid to respond to the ever-changing and rising energy demands of the 21st century.

The main objective behind developing a smart grid system is to improve efficiency and economy in energy conversion, transmission and distribution, storage and utilization. The need for a change over to a smart electric system arose when the new ways of producing energy without the emission of CO_2, effective management of loads where discussed for its consequences. The present communication system, particularly simulated by the internet, offers the possibility of monitoring and control throughout the power system and hence making it more effective and flexible providing lower cost of operation.

What makes the grid smart is that digital technology which allows a two-way communication between the utility and its customers where electricity and information can be exchanged mutually. The mandated target behind the smart grid technology platform is to strengthen the grid, develop a decentralized architecture for system control, delivering communication infrastructure, enabling an active demand side, integrating intermittent generation, enhancing the intelligence of generation, demand and the grid, capturing the benefits of distributed generation and storage and in preparation of electrical vehicles. Thus the technology will work with the electric grid to respond digitally to our quickly changing demand.

The benefits of introducing a smart power grid is to enable the demand response and demand side management through the integration of smart meters, smart appliances and consumer loads, micro-generation with the information to the consumers related to the energy use and prices. It helps in modifying their

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consumption pattern to overcome the constraints in power system. It also facilitates integration of all renewable energy resources, distributed generation, residential micro-generation and storage options by reducing the environmental impacts due to the power sector. The intelligent operation of the delivery system such as rerouting and working autonomously, provides means of aggregation thus pursuing efficient asset management. It also enhances secured and safe operation with enhanced power transfer capabilities by increasing the observability and controllability of the power grid.

2. SMART GRID ARCHITECHTURE

The smart grid consists of new information and communication technologies to revolutionize the electrical power system. The basic smart grid generally encompasses the entire electrical energy generation, transmission and distribution and utilization cycle. It consists of advanced actuators, sensors, communication infrastructure, IT systems, advanced monitoring, control and metering system with decision making applications. It has a network of communication, controls, computers, automation, new technology tools working together to make smart grid more efficient, reliable, secure and greener [1-4]. The smart grids relay on many advanced applications to deliver benefits to the customers and grid operators. These applications are programs, algorithms, data analysis and calculations that execute continuously or periodically on a computing platform on a single device or a subsystem or at system level that processes historical, real-time, or forecast the data with the objective to improve security, efficiency, reliability and economy.

The European technology platform defines Smart Grid as: *“A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure supplies.”*

According to US Department of Energy: *“A smart grid uses digital technology to improve reliability, security and efficiency of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources*”[5].

In Smarter Grids: The Opportunity defines as: “*A smarter grid uses sensing, embedded processing and digital communications to enable the electricity grid to be observable, controllable, automated and fully integrated.”*

2.1 Components of Smart Grid

2.1.1 Advanced metering equipment

The integration of Smart meters, communications networks, and data management system will provide the effective two-way communication between utilities and customers is called Advanced Metering Infrastructure (AMI) [4]. The function of AMI can be categorized as:

2.1.2 Market Applications

It serves to reduce labor, transportation, and infrastructure costs associated with meter reading and maintenance, increase accuracy of billing, involves customer participation for energy management.

2.1.3 Customer Applications

It serves to increase customer awareness about load reduction, enhances customer satisfaction.

2.1.4 Distribution Operations

Allows for the location of outages and restoration of service, reduces energy losses, improves performance in event of outage and optimization of the distributed system.

2.1.5 Smart Meters

Smart meters will provide knowledge to the customers about how much they pay per kilowatt hour and how and when they use energy. This will leads to better pricing and accurate bills in addition to ensuring faster outage detection and restoration by utility additional features involves tax credits, tariff options, participation in voluntary rewards programs for reduced consumption, remote connect or disconnect of users, prepaid metering. Smart meters have two functions:

1. Providing information about the energy usage to customers for helping them to control the cost and consumption.
2. Providing information to the utility for load factor control and development of pricing strategies based on consumption.

2.1.6 Smart Appliances

Smart appliances works in response to the signals sent by the utility. Appliances allow the customers to participate in voluntary programs which awards credits for limiting power use in peak demand periods or when the grid is under stress.Grid friendly appliances use a simple computer chip that can sense disturbances in the grid’s power frequency and can turn the appliance off for a few minutes to allow the grid to stabilize during a crisis.

2.1.7 Phasor Measurement Units (PMU)

The PMU’s carries the information such as bus voltage phasor, branch current phasors, in addition to locations and other network parameters. Measurements are taken from different points of the power system at the same instant with high precision, allowing an operator to visualize the exact angular dif-

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ference between different locations. It gives operators a time stamped snapshot of the power system.

2.1.8 Wide Area Monitoring Systems (WAMS)

WAMS are designed by the utility for optimal capacity of the transmission grid and to prevent the spread of disturbances. It gives early warnings of system disturbances for the prevention and mitigation of blackouts. It utilizes the sensors distributed throughout the network in conjunction with GPS satellites for accurate time stamping of measurements. The sensors will interface with the communication network.

The smart grid possess a wide range of attributes to cope with information delivery, power flow distribution, transmission line failures, energy storage systems, command and control of national infrastructure to achieve peak efficiency. The services will involve autonomous control of smart appliances, real time pricing adaptation, shifting of grid-tied power usage to non-stop peak periods, renewable energy management and closed loop demand response. The services acts as a platform for consumer engagement in load management, national energy independence and economic security. In all these processes the advanced metering infrastructure (AMI) system is a central access point for communication of information flows in the smart grid and micro-grid distribution networks.

2.2 Smart Grid Communications

It is one of the key features of the smart grid is the integration of modern communication network with the power systems. The communication network serves as the fundamental infrastructure to provide bidirectional end-to-end data communications in smart grid. Although a myriad of existing communication technologies can be applied to the smart grid, new communication protocols and enhancement of existing protocols are necessary to capture the unique characteristics and its requirements. The communication network architecture, potential communication standards and protocols for the construction of communication networks are to be known. The smart grid delivery system enhanced with communication facilities replaced the current power system with a more intelligent infrastructure. It is a complex network interconnecting with the large number of devices and systems with various ownerships and management boundaries.

The communication is either wired or wireless. The challenges posed by electricity from digital data for the design of communication networks for the smart grid is as follows:

- The electricity cannot be stored on a large scale when compared to digital data which can be stored easily in computer networks.
- Electricity is generated centrally and consumed locally. The routing of the networks are limited and long distance transmission is common.
- The Quality of Service (QoS) is the top priority in the smart grid unlike the Internet which uses Best Effort Delivery Service. QoS is crucial in order to satisfy the demand of consumers at any time in smart grid. Hence these features must be considered carefully in the design of network architecture and protocols for smart grid. The objective of the communication network is to provide a bidirectional end-to-end communication. The typical requirements for communication networks in Smart Grid is as follows:

- ***Reliability*** – The networks must be able to provide reliable communication that coincides with the reliability of the power grid itself.
- ***Scalability*** – The networks are expected to last decades and serve an ever increasing number of household appliances.
- ***Availability*** – Protection mechanisms, Redundancy, Fault tolerance with self-healing abilities must exist.
- ***Security*** – The networks must guarantee end-to-end encryption including the privacy of the networks from unauthorized access as well as confidentiality of communications across the networks.
- ***Low Latency*** – The latency requirement of some smart grid applications are demanding.
- ***Hard QoS*** – QoS services must be provided for smart grid applications with predictable latency and low rate error.
- ***Cost Effectiveness*** – The communication networks must be feasible and economic. The capital and operational expenditures must be low.
- ***Standards based and Interoperability*** – The standards on communication networks have to be developed to enable interoperability.

2.3 Overview of the network architecture

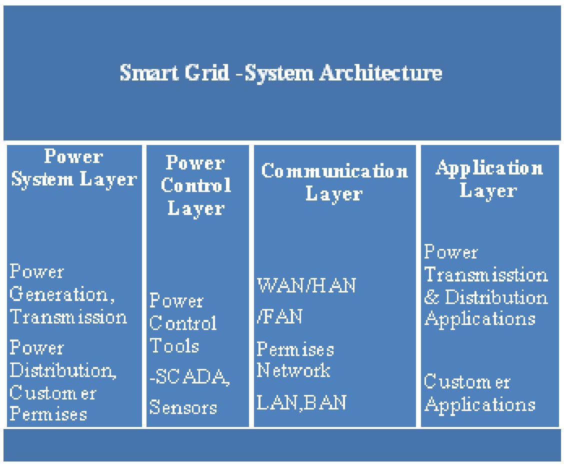

Figure1. Smart Grid-System Architecture

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The smart grid architecture is divided into four layers: the application layer, the communication layer, the power control layer and the power system layer from top to bottom and is shown in Figure. 1 [1,2], [6-8].Each layer is a set of similar systems that provide services and interfaces to the layer above it and receives services from the layer below it [1,2], [6-8].

2.3.1 Application Layer

The application layer provides the applications for customers and utilizes based on the information infrastructure. Under this layer two way sufficient, secure information exchange is provided for the upper-level applications in smart grid.

2.3.2 Communication Layer

The communication network layer has a hierarchical structure consisting of the premises network i.e., Home Area Network (HAN), Building Area Network (BAN), Industrial Area Network (IAN), Neighborhood Area Network (NAN), Field Area Network (FAN) and Wide Area Network (WAN) including the backhaul network, core network, and metro network according to their reach and functions in smart grid.

2.3.3 Power Control Layer

In the power control layer, the power control system such as (Supervisory Control and Data Acquisition) SCADA exists to enable functions for monitoring, control, management in the grid.

2.3.4 Power System Layer

The power system layer where the electric power flows via power generation, transmission and distribution systems.

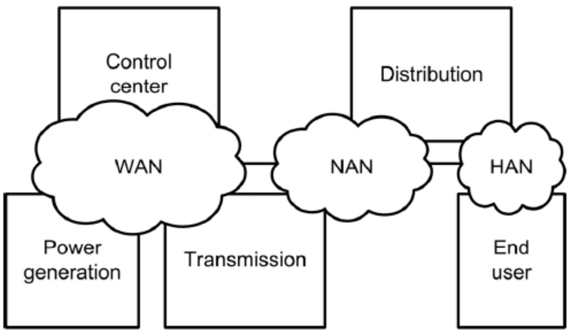

Figure 2.Communication Network Architecture for Smart Grid [9]

Here the communication can be separated as one layer to provide connectivity to the smart grid. Based on their reach and characteristics the communication networks are mainly of three types. They are the premises network, NAN / FAN, WAN. The Figure.2 illustrates the end-to-end communication networks for smart grid with multiple network segments and boundaries [9]. In this network, the premises network provides access to appliances in the customer premises. The NAN/FAN connects to smart meters, field devices and distribution panels. WAN provides long distance communication links between the grid and the utility core network. From the premises network to the WAN, the network complexity increases due to increasing network size and coverage area. Figure 3 shows the Communication Range and Data Requirement for different networks used in Smart Grid applications [8].

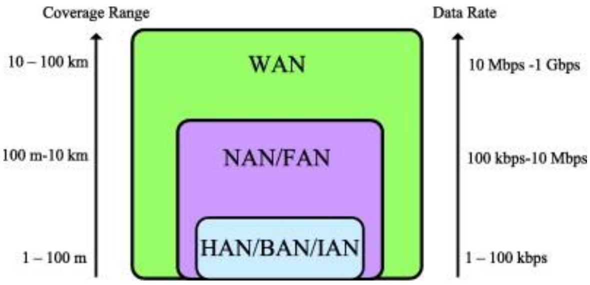

Figure 3.Communication Range and Data Requirement for different networks in Smart Grid [8]

The graph shows the communication range and data requirement for three types of networks in smart grid. The communication network should primarily be Internet Protocol (IP) based. This brings a number of benefits such as simplified field system architecture and control, end-to-end visibility, interoperability with different networks and support for existing IP applications. IP provides end-to-end communication based on packet switching and serves as a basic for upper layer applications, which enables applications to be developed without dependence on a specific data link layer protocol. This reduces the complexity in creating the upper layers of the smart grid applications. It serves as a unified interface for upper layer applications and provides good network scalability. The challenges, issues and security is the prime factor which decides the reliability of the Wireless Sensor Network (WSN) which helps to strength the communication network in Smart Grid [10].

2.4 Standardization Activities

As many utilities are in the process of implementing the smart grid technologies in their transmission, distribution and consumer systems, the smart grid projects have started to go far beyond smart metering. Thus there is an urgent need to establish interoperable standards and protocols. Standards are essential to develop, deploy and operate smart grid worldwide. In addition, the standards promote the application and commercialization of the smart grid technology by creating a competitive market for different vendors to compete based on prices and qualities.

TABLE I. COMMUNICATION STANDARDS IDENTIFIED FOR IMPLEMENTATION

Standards	Applications
Internet Protocol Suite	Foundation protocols for delivery of packets in communication networks for smart grid.
Open HAN	Used for HAN to connect utility metering systems
ZigBee	Used for HAN to connect to support Demand Side Management.
ANSI C12 Suite	Used for Smart Meters
IEC 61850 Suite	Used for Substation Automation
IEEE 1547 Suite	Used for Distributed Generation and Storage.
Open ADR	Used for Demand Response and Load Control.
DNP3	Used for Substation Automation

TABLE II. COMMUNICATION STANDARDS RELATED TO SMART GRID

Standards	Applications
Home Plug	In-home broad band power line communications.
ISO/IEC 12139-1	High Speed Power Line Communication Protocols.
ITU – TG.hn	In-home communication over power lines, phone lines and coaxial cables.
IEEE P1901	Broadband Communication over power lines.
IEEE P2030	Guideline for Smart Grid Interoperability.
IEEE 802 Family	Wired and Wireless Communication Standards
3GPP Family	2G, 3G, 4G cellular communication protocols.
ISA SP100	Wireless Communication Standards for industrial users.
Z-Wave	Wireless Mesh-Networking for HAN

Many standardization organizations have taken steps to expedite the development and implementation of smart grid. NIST (National Institute of Standards and Technologies) is one such U.S Agency whose primary responsibility is to coordinate the development of the framework that includes protocols and model standards for information management to achieve interoperability. In this framework, cyber security strategy and requirements are also included to analyze the security issue in the system. NIST along with other Standards Setting Organization (SSO's) developed 15 priority action plans to develop new standards or revise the existing standards to fill the gaps to ensure reliable, safe and secure operation. Table I & II shows the communication standards identified for implementation and standards related to smart grid respectively. IEEE, IEC, ITU-T, IETF are other standardizing organizations, that create standards to analyzes the issues related to networking and to discover the emerging attributes associated with the smart grid.

3. CLOUD COMPUTING

The significant transition to intelligent systems, make customers active participants involved in the power system by demand response and distributed generation. The utilities operate and manage the smart grid in a simple way using advanced data acquisition techniques and automation systems.

Resources are shared through Internet providing solutions, termed as Cloud Computing like the distribution of Electricity on the Grid. In the past, people would run applications or programs from software downloaded on a physical computer or server in their building, cloud computing allows people access to the same kinds of applications through the internet. E.g.: updating the Facebook status, checking the balance in the mobile phones are all just because of cloud. It delivers infrastructure, platform and software to customers [11].

Some of the benefits of cloud are flexibility, disaster recovery, automatic software updates, work from anywhere, document control, security, environmentally friendly.

3.1 Cloud in Smart Grid

Energy management is the process of monitoring, controlling, and conserving energy. In smart grid, energy management is a major concern. It is needed for resource conservation, climate protection and cost saving without compromising work processes by optimally coordinating several energy sources. The emergence of cloud computing provides an effective way to meet out the features involved in smart grid [3,12]. Cloud Computing Elements are grouped as Front end and Back end

Front end: End user interacts with the system through this front end. It is composed of a client computer, or the computer network of an enterprise and the applications used to access the cloud.

Back end: It provides the applications, computers, Servers and data storage that creates the cloud of services. The cloud concept is built on layers. It has three layers.

Infrastructure layer: Foundation of the cloud. It consists of servers, network devices, storage disk.

Middle layer: The middle layer is the platform. It provides the application infrastructure.
Top layer: The top layer is the application layer, the layer most visualize as the cloud.

3.2 Service Providers:

- Infrastructure as a Service (IaaS) has providers such as the IBM® Cloud.
- Platform as a service (PaaS) has providers such as Amazon's Elastic Compute Cloud (EC2).
- Software as a Service (SaaS) has providers such as Google Pack. [1, 12]

Some of the service providers of cloud are Amazon cloud services, Microsoft Azure, Google cloud platform, IBM cloud, Rackspace, VMware, Red hat, Oracle cloud, Verizan cloud, Navisite etc..,

4. DEPLOYMENT OF SMART GRID IN INDIA

The electric power grid represents entire apparatus of wires and machines that connects the sources of electricity (i.e., the power plants) with customers. Power plants convert a primary form of energy, such as the chemical energy stored in coal, the radiant energy in sunlight, the pressure of wind, or the energy stored at the core of uranium atoms, into electricity. At the end of the grid, at factories and homes, electricity is transformed back into useful forms of energy.

Indian electricity sector has witnessed tremendous growth in its energy demand, generation capacity, transmission and distribution networks. Keeping pace with the recent technological advancements, it is deploying new types of devices and ICT infrastructure, adopting new monitoring, control and energy management tools, and aiming at fast deployment of smart grid concepts at distribution as well as transmission level. Electricity, being a concurrent subject in India, both central government and state governments are responsible for its growth, operation and control [4]. According to Central Electricity Authority of India (CEA) report, All India Transmission System Capacity as on 30.04.2017 is shown in Table III.

TABLE III: POWER TRANSMISSION SYSTEM CAPACITY-INDIA (*SOURCE: CEA)*

765KV :	**400 KV:**
31,616 ckm	1,59,058 ckm
1,70,500 MVA	2,43,307 MVA
220 KV:	**HVDC:**
1,63,420 ckm	15,556 ckm
3,14,503 MVA	19,500 MW
Total	
3,69,650 ckm	
7,47,810 MVA	

The central transmission utility, Power Grid Corporation of India Ltd (POWERGRID), is responsible for national and regional power transmission planning, while the state sectors have separate state transmission utilities. The utility electricity sector in India has a National Grid with an installed capacity of 326.8 GW (as of 31 March 2017). The country's power installed capacity as on 31st March 2017 and energy consumption during April 2016-March 2017 have been 326.8 GW and 1114.41 TWh, respectively [4].

The Vision of India on Smart Grids is to "Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders". Department of Science & Technology (DST), Government of India has funded around US$ 46.5 million towards R&D on Smart Grids. Some of the functionalities/ technological advancements dopted for smart grids in Indian scenario are [4],

- Advanced Meter Infrastructure
- Peak Load Management
- Power Quality Management
- Outage Management
- Micro-grids
- Distributed Generation

The Government, utilities, universities, research institutions, industries supporting smart girds in India.

5. CONCLUSION

The successful operation of the Smart Grid requires flawless connectivity of technology. The available communication technology in India is at par with many developed nations in the world. However, there are issues in terms of interoperability of devices and systems with reference to smart grid deployment in utility environment. Cloud computing, an Internet Based Computing solution where the resources are shared like electricity distributed on the grid. Flexibility, disaster recovery, automatic software updates, work from anywhere, document control, security, environmentally friendly are the unique features of cloud computing in Smart Grid applications will give the reliable and efficient power to all.

REFERENCES

[1] Berthold Bitzer, and Enyew Sileshi Gebretsadik (2013), "Cloud Computing Framework for Smart Grid Applications", *IEEE Power Engineering Conference,* DOI:978-1-4799-3254-2/13/IEEE, pp 1-5.

[2] Sadia Fayyaz, Muhammad Mohsin Nazir, (2012), Handling Security Issues for Smart Grid Applications using Cloud Computing Framework, *"Journal of Emerging Trends in*

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International Journal of Advances in Computer and Electronics Engineering
Volume 2, Issue 11, November 2017, pp. 11–17

Computing and Information Sciences", ISSN 2079-8407, VOL. 3, NO. 2, February 2012, pp 285-287.

[3] Dr. Kishor M. Dhole, Dr. A. B. Manwar, Dr.Vinay Chavan, (2014), Smart Grid Approach to Improve Power Utilization in Cloud Computing Environment", *International Journal of Advanced Research in Computer Science and Software Engineering,* ISSN: 2277 128X, Volume 4, Issue 4, April 2014, pp 793-796.

[4] *"India Country Report, Research, Development, Demonstration and Deployment of Smart Grids in India",* Government of India, Ministry of Science & Technology, Department of Science & Technology, New Delhi , June 2017.

[5] Maria Kopsakangas-Savolaien, Rauli Svento., (2012), "Modern Energy Markets: Real Time Pricing Renewable Resources and Efficient", Springer, pp 120-121.

[6] Mohammad Nour Hindia, Ahmed Wasif Reza, Omar Dakkak, Shahrudin Awang Nor , and Kamarul Ariffin Noordin, (2014), "Cloud Computing Applications and Platforms: A Survey", *The 3rd International Conference on Computer Engineering and Mathematical Sciences (ICCEMS 2014)*, pp 515-524.

[7] Neeraj Kumar, Sherali Zeadally, Subhas C Misra, (2016), "Mobile Cloud Networking for Efficient Energy Management in S mart Grid Cyber - Physical Systems", IEEE Wireless Communications-October 2016, pp100-108.

[8] Murat Kuzlu, Manisa Pipattanasomporn, Saifur Rahman(2014), "Communication network requirements for major smart grid applications in HAN, NAN and WAN", *ELSEVIER Computer Networks*, Vol 67,pp 74-88.

[9] Zoran Bojkovic, Bojan Bakmaz (2012), "Smart Grid Communications Architecture: A Survey and Challenges", *Recent Researches in Applied Computers and Computational Science,* ISBN: 978-1-61804-084-8, pp 83-89.

[10] Vikas Juneja, D.V. Gupta (2017), "Strategies for Detection and Prevention of Vampire Attack in WSN", *International Journal of Advances in Computer and Electronics Engineering,* Volume: 02 Issue: 02, February 2017, pp. 13-16.

[11] Leena Mhatre (2016), "The Basics of Cloud Technology", *International Journal of Advances in Computer and Electronics Engineering*, Volume: 01 Issue: 02, June 2016, pp. 27- 30.

[12] Fengji Luo, Zhao Yang Dong, Yingying Chen, Yan Xu, Ke Meng, Kit Po Wong, (2012), "Hybrid Cloud Computing Platform: The Next Generation IT Backbone for Smart Grid" *2012 IEEE Power and Energy Society General Meeting*, DOI: 978-1-4673-2729-9/12/IEEE, pp 1-7.

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