Novel Approach to Synchronize National Knowledge Network (NKN) of National Informatics Centre (NIC) Network with IST Over IoT Framework

Pranalee Premdas Thorat, T. Bhardwaj, P. Kandpal, Ravinder Agarwal, D K Aswal

Abstract: ***The successful commissioning of the proposed methodology to synchronize the NIC-NKN in Delhi and Hyderabad with Indian Standard Time (IST) maintained by NPLI over NTP protocol over IoT framework is a significant accomplishment in the field of time synchronization. The proposed methodology utilizes an IoT framework along with a unique Stratum 1 NTP architecture that is supported by a pre-calibrated Rubidium frequency source. This architecture enables the establishment of stratum 1 synchronization at the two locations, thereby ensuring that the time is accurately synchronized with the NPLI maintained Indian Standard Time (IST). The successful implementation of this methodology has several benefits. Firstly, it ensures that the time at the NIC-NKN in Delhi and Hyderabad is accurate and synchronized with the Indian Standard Time (IST) maintained by NPLI. This is crucial for various applications where precise timing is critical, such as in telecommunications, financial transactions, and scientific research. Secondly, this methodology can be extended to other locations and organizations that require accurate time synchronization. With the increasing use of IoT devices, the need for accurate time synchronization is only going to increase. This methodology provides a reliable and scalable solution that can be easily implemented in various organizations and locations. Thirdly, the use of pre-calibrated Rubidium frequency sources ensures that the time synchronization is accurate and stable over a long period. This is important as small inaccuracies in time synchronization can accumulate over time and result in significant errors. The use of pre-calibrated Rubidium frequency sources ensures that the time synchronization is accurate and stable over a long period, thereby avoiding such errors. In conclusion, the successful commissioning of the proposed methodology to synchronize the NIC-NKN in Delhi and Hyderabad with Indian Standard Time (IST) maintained by NPLI over NTP protocol over IoT framework is a significant accomplishment.***

This methodology provides a reliable and scalable solution that can be easily implemented in various organizations and locations to ensure accurate time synchronization.

Keywords: ***NIC-NKN, NTP, NPLI., (IST), Framework, Network, IoT, Informatics***

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I. INTRODUCTION

National Knowledge Network of National Informatics Centre (NIC-NKN) has the mandate to provide nationwide seamless hi speed internet network. Similarly NPLI, being NMI of India has the mandate to maintain and provide traceability of IST. The requirement from NIC-NKN falls under the umbrella of NMI for synchronizing their network across PAN India with millisecond accuracy. The traceability maintained by NPLI is offered to NIC-NKN via a consultancy project. In this project two high speed network (Gbps) data centers situated at New Delhi and Hyderabad, India serve as core Data centers ofPAN India. A network analysis of the existing architecture of NIC-NKN was carried out. After studying the architecture which is based on seven cores of their network across India a novel methodology was proposed to NIC-NKN. As per proposed methodology it was suggested that by adopting architecture of Internet of Things (IoT), their two centers, located at National Data Centre (NDC), Shastri Park, New Delhi and Disaster Recovery Centre (DRC), Hyderabad will be synchronized to IST over Network Time Protocol (NTP) architecture. These centers have provision of traceability to IST at CSIR-National Physical Laboratory via Common view Global Navigational Satellite System (CVGNSS) method. This project presents the novel Stratum 1 NTP architecture based on Rubidium frequency source perfectly mapped under IoT framework. This paper presents the successful commissioning of this architecture in the IoT framework. IoT is a domain which iscapturing all the smart devices and sensors operating in the range of nanoseconds to few seconds in a interconnected fashion with asynchronous geographical distribution. In this domain various data centers are sharing their data not only for redundancy but also to provide backup services in a mirrored approach.

IoT framework provides functionality as well as architectural growth in incremental fashion without disturbing or changing the basic internal network architecture of any data center. Hence it was the most suitable framework for the present case study.

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As in the pilot phase of this study only two core data centers of NIC network has to be synchronized. And after successful commissioning the other data centers of the NIC network across PAN India can be added as an incremental node in the already synchronized core network. This case study will pave the way for connecting geographically distributed data centers over a same synchronized time stamp. This work highlights the novel approach to synchronize millisecond accuracy requirement applications like ISP, VOIP services in the country in the upcoming IoT framework.

II. OVERVIEW OF PROJECT

Designing a project proposal to satisfy the synchronization demand for an organization like NIC-NKN is a difficult task as NPLI is not having any ready to deliver all in a box solution for such strategic users. Hence it is important to understand the nature of the organization. This solution provided to NIC-NKN considering their organization structure and scalable requirement is one of its kind. Moreover this solution is extremely economical with all the benefits of synchronization. In this section, brief overview of NIC-NKN is given which will help to understand the criticality of this synchronization project.

A. Significance of Nic-NKN

NIC also known as the technology partner of Government of India. The NIC was established in 1976. The Ministry of Electronics and Information technology (MeitY) is the parent organization of NationalInformatics Centre. The headquarter of NIC is in New Delhi. The main function of NIC is to disseminate the IT services provided by the Government. It provides the infrastructure which is required to disseminate the initiatives of Digital India across the community. The NIC helps to distribute the e-governance to the masses and it provides a number of digital services including Government Local Area Networks(LANs), Video Conferencing, NKN, Email & Messaging, Remote Sensing & GIS, Webcast, Domain Registration, National Cloud, Command and Control, NICNET, Data Centre and Many More. NIC is the responsible for managing the NKN. NIC has Four National data Centers in New Delhi, Hyderabad, Pune and Bhubaneshwar and 36 state centers.

NKN[1] is a network which is widely spread over the country as shown in Figure 1. The main aim of NKN is to create a knowledge society by interconnecting all the institutions of higher learning and research. The objective is to establish a high speed communication network so that the institutions can share the knowledge easily. It is also known as multi-gigabit national research and education network. This network is managed by NIC[2].

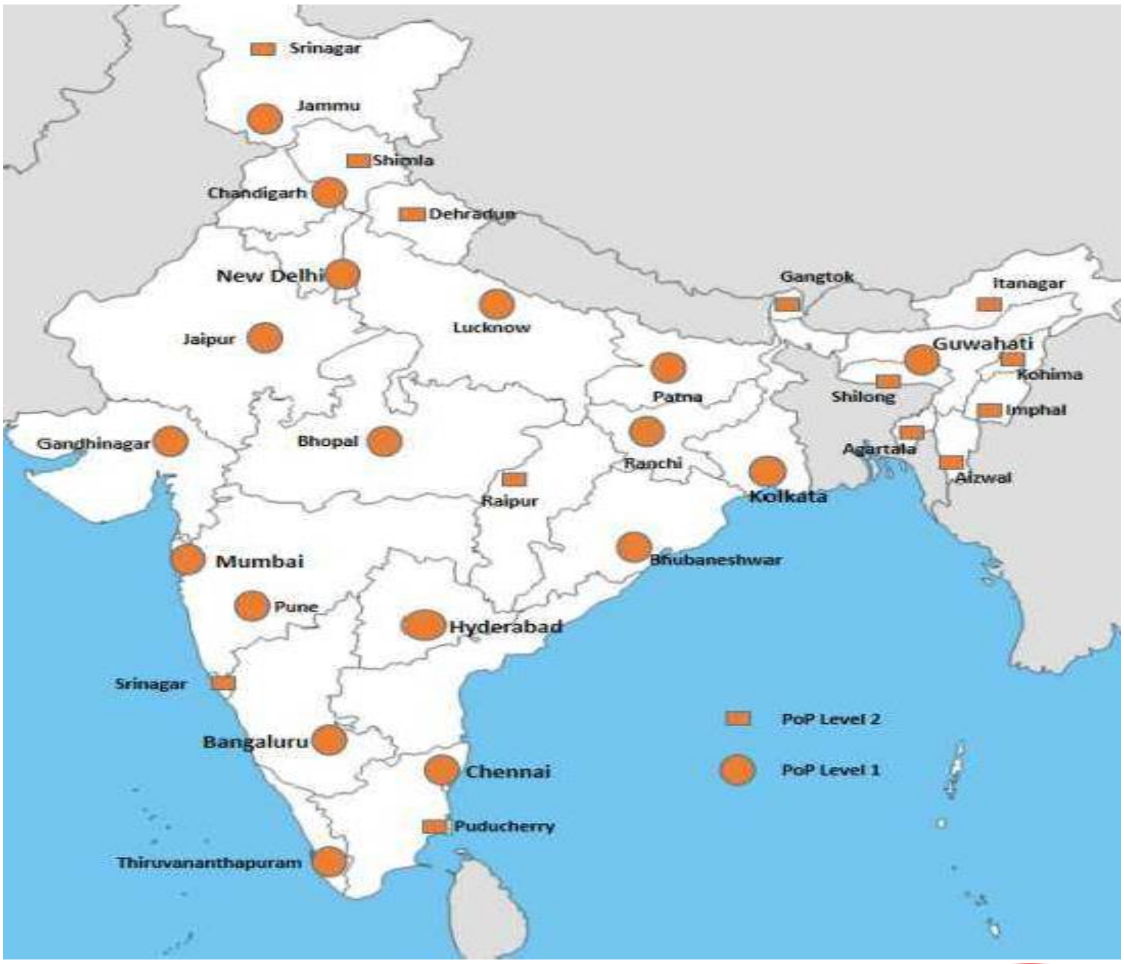

Figure 1: All the Point of Presence (Po Ps) of NKN

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NKN was formulated in 2010 and it serves two countries: India and Bhutan. The NKN is a hierarchical network and it contains three layers: ultra-high speed CORE: Level 1,Distribution: Level 2 and Edge: User Level(refer to Fig 2.). There will be 18 core Point of Presence (PoP)s and around 25 Distribution PoPs across the country. The connectivity between Core PoPs above . The PoPs will use different links provided by National Long Distance Service Providers(NLDs) to form the NKN Backbone. These PoPs will be connected in a mesh. In the Layer 1, the Core PoPs are connected to each other and the metro cities i.e. Delhi, Mumbai, Chennai and Kolkata will be connected via Dark Optical fibre. In the next Layer, the Core PoPs will be connected to the distribution PoPs. Distribution PoPs are located in different states. Then in the user level, the NKN PoPs will directly be connected to the research and educational institutions.

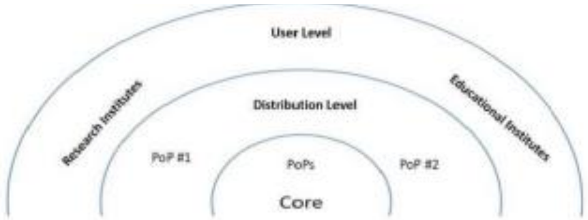

Fig 2: Hierarchy of NKN

B. Role of CSIR-National Physical Laboratory

The National Metrology Institute (NMI) has the responsibility of maintaining the various standards. Being a NMI of India, NPLI has the responsibility to maintain time standard along with other physical parameter like length, mass luminescence etc. In India CSIR-National Physical laboratory (NPLI) isa custodian of IST (IST is now trademarked of time by NPLI). In other words, NPLI maintains local time of the nation with the help of stable frequency sources like atomic clock. As SI second is defined as "9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom at 0 Kelvin". The cesium (Cs) clock, Active Hydrogen Maser(AHM), Passive Hydrogen Maser(PHM) etc are used to realize local timescale by all NMIs including NPLI which is NMI of India. Some of the NMIs have also developed and are using Cs Fountain frequency standard and even optical frequency standards. IST is developed with the ensemble of Cs atomic clocks, AHMs, PHMs. This IST is traceable to BIPM with the help of GNSS links and TWSTFT links. TWSTFT link is not operational currently but multiple GNSS links are usedto maintain traceability with BIPM. The uncertainty of UTC(NPLI) or IST is 3 nanoseconds which is extremely good. In NPLI Time and frequency division is continuously working towards improvement of the standard as well as improvement in dissemination of the same. NPLI is also working towards development of advanced time standard like Cs fountain Clock, which was operational in 2014-15[3]. An extensive efforts are going on towards development of Optical frequency standard[4]. Along with primary time scale, NPLI has also developed back up timescale which is also now fully operational. These two Timescale set up are located approximately 450 meters apart and is interconnected as shown in Figure 3.

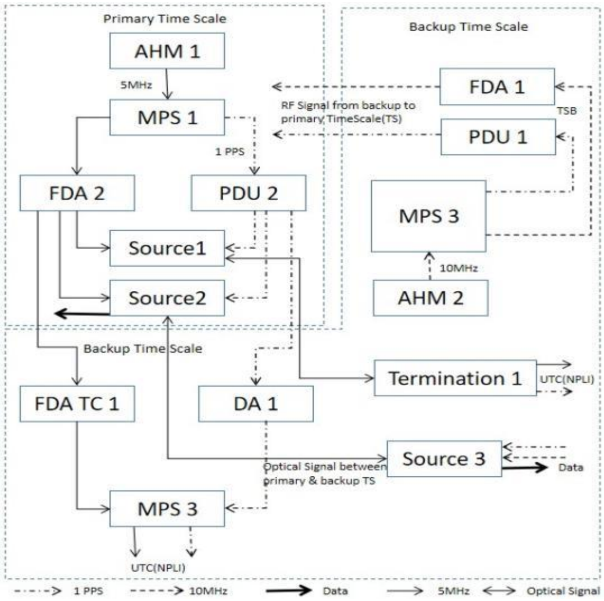

Fig 3: The figure contains the primary and secondary timescale setup established at NPLI. These two Timescale set up are located approximately 450 meters apart and is interconnected

There are various dissemination services which are also offered to the users. Like Telephone time dissemination, NTP time dissemination[5,6] etc. Time Dissemination service in the name of Teleclock was very popular service for masses as it offered 1 second accuracy with existing PSTN infrastructure[7,8,9,10,11]. But with technology advancement this service was shut down in 2016. A revised version of this service in the name of Fonoclock is under development. NTP time dissemination service is also very popular and is currently the only active time dissemination service provided for masses from NPLI. Users can avail NTP service using domains "time.nplindia.in". Stack of high end NTP servers provide this service 24 by seven across the nation as shown in Figure 4.

Fig 4: Figure represents the stack of NTP servers providing NTP services at NPLI. These servers provide the time over internet using NTP

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NPLI is also providing special solutions to various users whose requirement is typical. For example a special solution was provided to CSIR-Central Road Research Institute's network survey vehicle for their GPS calibration[12]. Similarly when NIC-NKN requirement came , it was first studied about the accuracy requirement of their application. And it was finalized to provide a NTP based synchronization solution built upon the synchronization requirement. Out of four Data centers two core data centers were chosen for setting up stratum 1 synchronization center.

III. INTERNET OF THINGS FRAMEWORK

IoT can be treated as a superset of connecting devices that are uniquely identifiable by existing near field communication (NFC) techniques. Also, it has demonstrated that the IoT is a network of connected things, where things are remotely associated by means of sensors[13]. This feature makes IoT extremely suitable for typic l synchronization requirements like NIC-NKN. Sensors, Actuators, RFID Tags, cloud servers are the major components of IoT. ensors/Actuators are of two different types of transducers. The transducers convert some physical signals to electrical impulse. Sensors and actuators are worked in reverse order, sensors collect information and route it to the data centers for taking decisions with a corresponding command sent back to an actuator in response to that sensed input. RFID Tags works through unique addressing system used to effectively identify and communicate to devices [14] and the cloud servers where all the received data is stored. These components are organized in the design of IoT to enable interaction of heterogenous devices and components are used by the sensing or hardware layer of IoT which are presented by layered architecture of IoT. This makes layered architecture of IoT suitable for various timing applications. In this paper efforts are made to utilize the IoT framework for designing time synchronization solution for the first time for any user.

A. The Layered Design IoT Architecture

varies from application to application, based on the area of application which we intend to build. IoT platform majorly use four main components like sensors/actuators, devices, gateway, and cloud, over which architecture is framed. The integration of these components makes the layered design of IoT. The various layers with their relevance to proposed solution is discussed below [14]. Sensing Layer or a hardware layer consist sensors, actuators, RFID tags, edge processors etc. such kind of embedded devices for sensing and information collection of physical worlds. The smart objects or other physical parameters of physical environment are identified by the hardware devices of this layer. In the proposed solution for the synchronization of NIC data centers, the antenna structure mounted at two locations along with processing devices are configured in sensing layer of this architecture. (ii)Gateway Layer data received from above layers is handled at this layer. It routes the information and also enables communication among cross platforms. This layer for the proposed solutions is configured at NMI CSIR-NPLI Firewall and Router of NIC to route the timing signals from stratum 0. Middleware layer is an interface between the application and hardware layer. Due to the heterogeneity of 'Things' and lack of standards it plays a key role and provides communication between applications. It is also responsible for data and device management, semantic examination, data filtering, access control, discovery of data like object naming service and electronic product code data administration. This layer is configured at both Data center of NMI and Data Center of NIC for processing the timing signal and checking for uncertainty for final requested time with higher accuracy. Application Layer is the top most layers enable the interaction between users and applications. This layer is used to provide a user interface for using IoT smart applications such as: agriculture, road monitoring, pollution monitoring, healthcare, retail, public safety, smart home etc. With the expanding development of RFID innovation, various applications are advancing which will be under the umbrella of IoT [15]. This layer is configured at NIC Data Center for synchronizing the users of NIC via there internal network and Router for WAN user across nation. The implementation of IoT platform to make the things smart needs several technologies and protocols. The technologies and protocols used by different layers make the IoT devices to communicate with each other [16]. The next section gives a brief overview of IoT layers protocol and technologies used.

B. Technologies/standards/Protocols of IoT

This section detailed the data layer or messaging protocols and network layer protocols which help the IoT to establish communication between billions of IoT devices and are tested for designing the proposed solution.

C. Messaging Protocols of IoT

Messaging Queuing Telemetry Transport Protocol (MQTTP) is designed for Machine-to-Machine communication. It is a lightweight messaging protocol of IoT for data transmission between users and servers. It requires little bandwidth and uses a client server model for different operations like publish and subscribe the data. Constrained Application protocol (CoAP) was developed as a standard (RFC 7252) [17] and is designed for IoT systems based on HTTP protocols. This is analogous to NTP client – server communication model in the proposed solution.

D. Network Protocols of IoT LoRa WANP

(Low Power Wide Area Network Protocol) used for networks of wide area and it's made to connect millions of low power devices in a huge network such as smart cities [18]. It uses frequency range of 2-15 km with data rates 0.3-50 kbps and provide low-cost bidirectional communication. The various users, however small or big accessing NIC's NTP services can be mapped under this IoT protocol. This makes the proposed solution relevant to any time synchronization application.

IV. SYNCHRONIZATION OF NIC-NKN NETWORK

It is extremely important to synchronize national and state data centers of NIC-NKN involved in management of IT infrastructure of Central Ministries/Departments over heterogeneous.

Networks functioning with a speed of multi-gigabits per second. This network connects R & D institutions/organizations, national universities and medical institutions. also network connectivity over optical fibre cable is provided to state government secretariats with hub connectivity to the central government. Hence synchronizing this network backbone of Digital India Mission was of crucial importance A novel methodology was proposed to NIC-NKN which suggest that by adopting basic architecture of Internet of Things (IoT), their two centers, located at National Data Centre (NDC), New Delhi and Disaster Recovery Centre (DRC), Hyderabad will be synchronized to IST using NTP architecture [19]. The architecture proposed is based on a pre-calibrated Rb frequency standard, multichannel GNSS receiver and a dedicated high end NTP server as shown in figure1. These two centers are now successfully synchronized. For the first time IoT architecture (with M2M communication) based IST synchronization was implemented, details of which will be presented in the paper. With a limited degree of programmability and customization in the network architecture of NIC-NKN, the synchronization of IST has been achieved with offset ranging from 0.3 to 0.5 milliseconds and jitter in few microseconds. The architecture was designed around four major components working at different layers. The major components of this architecture are sensor/actuators, smart devices, gateways, middleware devices and application.

V. IMPLEMENTED NOVEL IOT ARCHITECTURE

The synchronization accuracy required by NIC-NKN over the network was of the order of milliseconds. Hence NTP was the best solution to synchronize their network [20, 21]. However, as the network synchronization is extremely critical it must not have any reason for failure. Hence it was proposed to set up stratum 1 server at two of their main locations. After Strategically analyzing the network, site at Delhi and Hyderabad was finally selected for creating as stratum 1 station. As the NKN requirement comprises to synchronize their network over NTP a rubidium frequency source was selected. To regularly monitor the performance of the rubidium frequency source, a GNSS receivers was also installed at site. However, the building belongs to other government body and has multiple restrictions as for security issues. The real critical issue was faced during installing the GNSS antenna. There was no place available considering various stringent laws and the locations which were available were having line of site issues. However ultimately. on the rooftop of almost 12 story building with no direct rooting available. However, it was finally managed to install rooftop antenna but the antenna cable length was 210 meters. In order to get the signal down till receiver a LNA amplifier was also installed. A workstation is recording the GNSS data 24 by 7 which is referred back to NPLI regularly. Once in a while, the Rubidium frequency standard is calibrated to maintain the performance. The NTP server is directly connected to rubidium frequency source which makes it a stratum 1 server. The output of NTP server is fed to the switch of NIC-NKN. This switch then further synchronizes the local network of NIC-NKN. Both the centers (Delhi and Hyderabad) are synchronized in same fashion. However, these stratum 1 servers are further layered by stratum 2 servers by NIC-NKN. They have connected it over a full mesh so that even if one side of network fails, the other side can still synchronize the entire network. The kind of layered architecture provided here is the novel IoT layered architecture. The implementation of IoT platforms to make applications smart needs several technologies and protocols. The technologies and protocols used in this architecture at different layers are mainly TCP/IP and UDP protocols. In Indian perspective first time a novel IoT based Time Synchronization architecture is successfully implemented at two core locations of NIC-NKN which due to its scalable nature paves the way for future applications where requirement of IST synchronization is crucial. The architecture and Block Diagram are shown in Fig 4 & Fig 5 respectively.

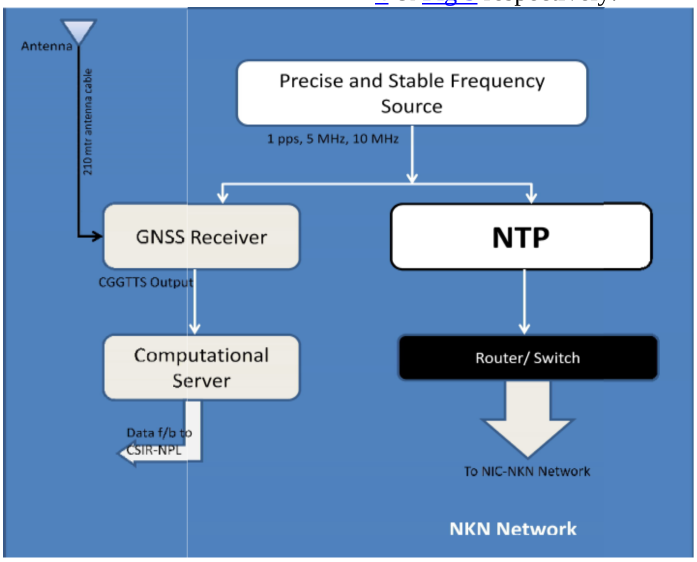

Fig 5: Block Diagram of Stratum 1 Architecture Deployed at NIC-NKN sites

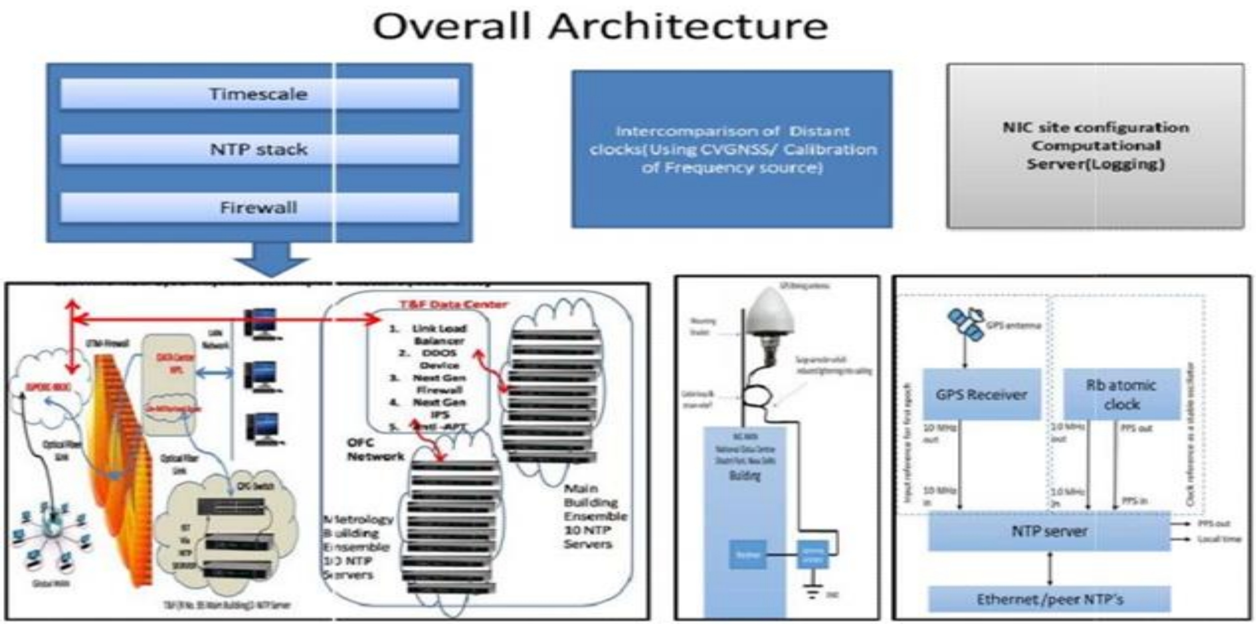

Figure 6 Overall Architecture in site of IoT

A. Successful Deployment Result

This solution was successfully deployed at both the sites. The successful installation andcommissioning at Delhi and Hyderabad sites is illustrated in the following Figures i.e. 6,7,8,9,10.

Figure 7 Antenna Installations at NIC-NKN

Glimpses of Successful Deployment at Delhi Site

Figure 8 Stratum 1 NTP server at Delhi

Figure 9 Team of NIC-NKN, Delhi

Fig 10: Stratum 1 NTP server at Hyderabad site

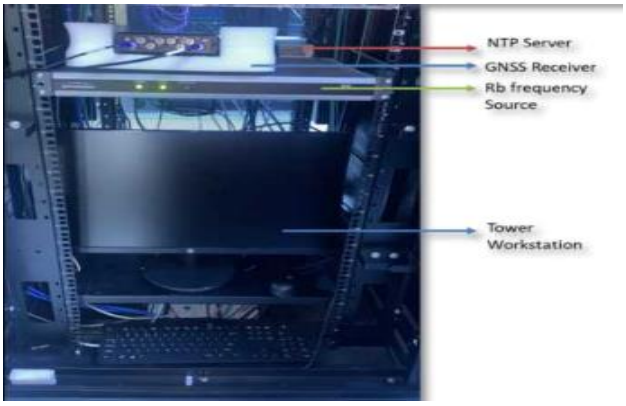

Fig 11: Deployment at Hyderabad

VI. MEASUREMENT RESULT AND CONCLUSION

After Installation at Delhi site, the performance of NTP server was studied to verify the implementation. The results are extremely encouraging as the delay is well concentrated within the range of 0.3 to 0.5 ms. Hence the similar set up can be used for multiple applications. The performance of stratum 1 in terms of delay is shown in Figure 12.

This paper paved the way for upcoming IoT applications of the nation which required critical real time synchronization as well as established a successful architecture deployed using NTP protocol andCVGNSS technologies. Due to its scalable nature this solution can be extended to any application of similar nature. This is a cost effective solution as it does not involve Cs atomic clock. The future of research might be useful to address the requirement of various timing solution in a cost effective way for multiple applications like, Certifying Authorities, Banking, Telecommunication, Stock exchange, VOIP and ISPs etc. This Rubidium based solution with IoT framework can be extremely useful for developing countries like Sri Lanka, Nepal, Bangladesh as well.

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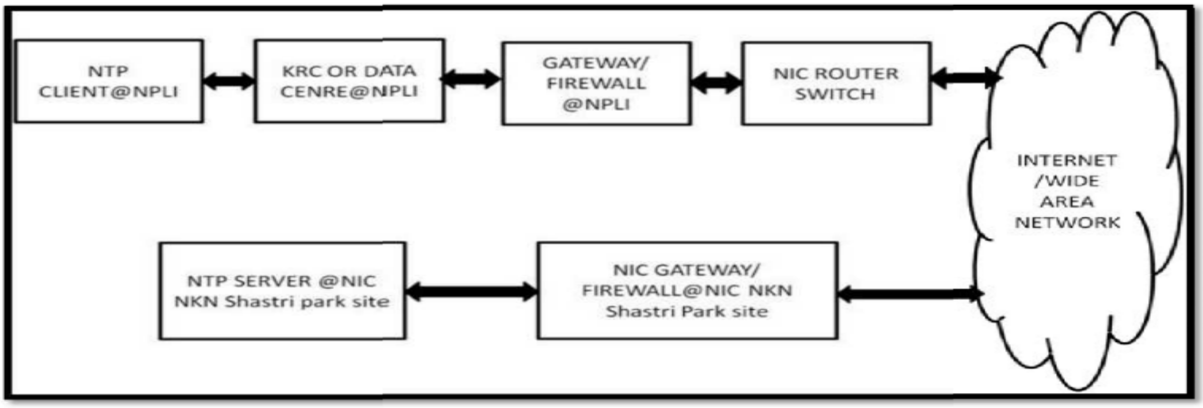

Fig 12: Flow Diagram for Evaluating NTP server's Performance at Shastri Park site

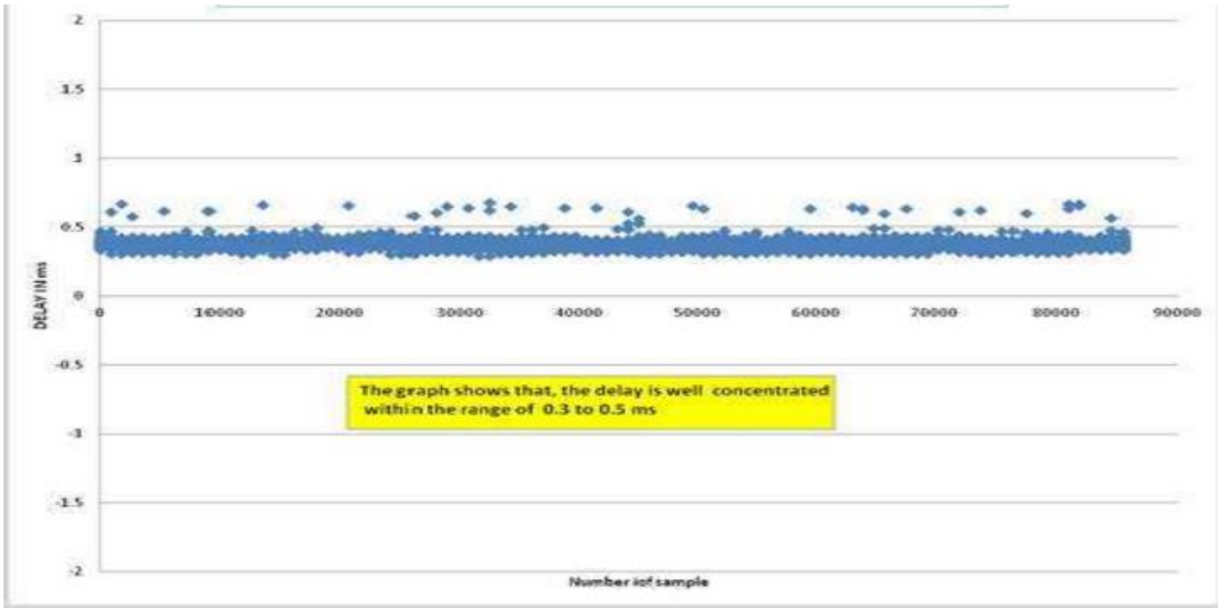

Fig 13: Delay in ms w.r.t. UTC(NPLI) measured at the site of NIC-NKN, Shastri Park, New Delhi

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DECLARATION

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Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	Dr. Ravinder Agarwal and Dr. D. K. Aswal -contributed as mentors in the entire project work. Preeti Kandpal- contributed as technical assistance in the fulfillment of the project work. Trilok Bhardwaj- Contributed as a Co-PI and worked on IoT aspects of the project work. Pranalee P Thorat- The Main Contributor and Project Investigator of this project were instrumental in conceptualizing, implementing, executing, and analyzing the research work.

REFERENCES

1. https://www.nic.in/services-main-page, Accessed on: 2 Feb 2022.
2. https://www.nic.in/servicecontents/nkn Accessed on: 2 Feb 2022.
3. Aishik Acharya, Vattikonda Bharath, Poonam Arora, Suchi Yadav, Ashish Agarwal, Amitava Sen Gupta "Systematic Uncertainty Evaluation of the Cesium Fountain Primary Frequency Standard at NPL India", MAPAN-Journal of Metrology society of India, Vol.32, 2017, pp. 67-76. [CrossRef]
4. Lakhi Sharma, H Rathore, S. Utreja, Neelam, A. Roy, S.De& S. Panja "Optical Atomic clocks for Redefining SI Units of Time and Frequency", Mapan, october 2020,vol. 35, pp. 531-545. [CrossRef]
5. DCNET Internet Clock Service, D.L. Mills, COMSAT Laboratories,18 April,1981 (RFC-778)
6. David L.Mills, "Network Time Protocol(Version 3) Specification, Implementation and Analysis", RFC-1305, 1992-3. [CrossRef]
7. Improved Version of Teleclock Receiver Utilizing Mobile Telephone Network Gcc 09/01/2012 16564 ThoratPranaleePremdas, Suri Anil Kumar. Banerjee Parameswar,
8. Improved Teleclock Receiver Utilizing ThoratPranalee P, Suri Anil Kumar. obile Telephone Network 1390DEL2009 07/07/2009 Banerjee Parameswar.
9. Improved Version of Teleclock Receiver Utilizing Mobile Telephone Network 04/12/2009 PCT/IB2009/ 07602 WIPO, Geneva Banerjee Parameswar, ThoratPranaleePremdas, Suri nil Kumar.
10. P. P. Thorat and P. Banerjee, "Use of Teleclock Service to Synchronize Computer Clock", MAPAN - Journal of MetrologySociety of India, Vol. 26, No. 2, 2011; pp. 91-96. [CrossRef]
11. P. Banerjee, P. P. Thorat, A. K. Suri, "An Innovative Time service via Telephone Network - A study on its Potentiality",2009IEEE International Frequency Control Symposium Joint with the 22nd European Frequency and Time forum, Besancon, France, DOI: 10.1109/FREQ.2009.5168281, pp. 733 -737. [CrossRef]
12. P. Banerjee and P.P. Thorat " Evaluation of performance of GPS Receiver in CRRI Network Survey Vehicle" MAPAN-Journal of Metrology society of India, Vol.24, No. 4, 2009, pp. 233-239. [CrossRef]
13. Shang Guoqiang, Chen Yanming et. al. "Design and Implementation of a Smart IoT Gateway." IEEE International Conference on Gree n Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing, 2013 [CrossRef]
14. Jasmin Guth, Uwe Breitenbücher, Michael Falkenthal, Paul Fremantle, Oliver Kopp, Frank Leymann, Lukas Reinfurt "A Detailed Analysis of IoT Platform Architectures: Concepts, Similarities, and Differences" in book "Internet of Everything: Algorithms, Methodologies, Technologies and Perspectives" Springer 2018
15. Govinda K, Saravanaguru R.A.K " Review on IOT Technologies." International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 4, 2016
16. Samie, F., Bauer, L. & Henkel, J. 2016. IoT technologies for embedded computing: A survey. Hardware/Software Codesign and System Synthesis (CODES+ ISSS), International Conference. [CrossRef]
17. Z. Shelby, K. Hartke, C. Bormann, The Constrained Application Protocol (CoAP), Internet Engineering Task Force, June 2014 (RFC 7252) [CrossRef]
18. Ramon Sanchez-Iborra; Jesus Sanchez-Gomez; Juan Ballesta-Viñas; Maria-Dolores Cano; Antonio F. Skarmeta (2018). "Performance Evaluation of LoRa Considering Scenario Conditions". Sensors. 18 (3): 772. Bibcode:2018Senso..18..772S. doi:10.3390/s18030772 [CrossRef]
19. Pranalee P. Thorat, PreetiKhandpal, and Trilok Bhardwaj, "A Study and analysis of stratum 1 set up establishment at NIC-NKN Delhi for IST synchronization of NKN network" URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019.
20. PThorat and P Benerjee , Algorithm and preliminary observations of new time scale of NPLI, 2011 XXXth URSI General Assembly and Scientific Symposium, IEEE Xplore 2011. [CrossRef]
21. David L. Mills "Computer Network Time Synchronization-The Network Time Protocol", 1st Edition, pp. 12, 2006.

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Pranalee Thorat is a highly accomplished researcher and scientist in the field of Time and Frequency with Time Dissemination and Electronic Engineering and Engineering Physics. She obtained her M.Tech degree in Electronics and Communication Engineering from VNIT, Nagpur, and has since dedicated her career to researching and developing cutting-edge technologies in this field. Currently, Pranalee is a Principal Scientist at the Division of Time and Frequency Standards (NPL) at the National Physical Laboratory in India. Over the course of her career, she has been involved in numerous research projects and has secured funding for many externally-funded projects as a project leader. In addition to her research work, Pranalee has also made significant contributions to the academic community through her publications in prestigious SCI and Scopus journals. She is a member of many prestigious societies like IETE, IEEE, MSI, and has been recognized for her outstanding contributions to the field with three national International patents. She has achieved three young scientist awards at various International forums as well. Overall, Pranalee Thorat's exceptional achievements and contributions to the field of Time and Frequency with Time Dissemination make her a highly respected and valuable member of the scientific community.

Trilok Bhardwaj is Principal Scientist in Time and Frequency Group of Indian Standard Time division of CSIR-NPL as a Cyber Security expert for secured dissemination of time across networks. He received his MTech in Computer Science & Engineering degree from AAIDU, Allahabad. He hasreceived two other master's degree in Electronics Science and Computer Science from Kurukshetra University Kurukshetra and MDU Rohtak after graduate degree in Science from Kurukshetra University Kurukshetra. He has worked in ISRO (Indian Space Research Organization) in the field of GIS prior to joining CSIR-NPL. He has been pursuing his Ph.D in the field of IoT in ACSIR -NPL. His primary research interest is in Cyber Physical System, Cyber Security and IoT across Industry 4.00

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Dr. Ravinder Agarwal is currently Professor and Head in the Electrical and Instrumentation Engineering Department, Thapar Institute of Engineering & Technology, Patiala. Dr. Agarwal obtained his Ph.D. in 1991 from H P University, Shimla. Dr. Agarwal has about twenty four years of teaching experience. His current area of research interest includes Biomedical Instrumentation, Environment Monitoring Instrumentation, Sensors & Transducers, Rehabilitation devices and sports cognition. He is fellow of many prestigious societies like IETE, IE, Ultrasonic Society of India, Metrology Society of India. He is Life Member of Instrument Society of India (763). His broad research area is Biomedical Instrumentation. He has many Honors and awards in his achievement list. He has led many DST/Meity sponsored projects, published multiple journal papers and delivered numerous expert talks.

Dr. D. K. Aswal joined the Bhabha Atomic Research Center in 1986, where he is currently the Director of the HEALTH SAFETY & ENVIRONMENT GROUP, He served as director NPLI earlier. He did his Ph.D in Physics from Mumbai University and M.Sc. in Physics (Gold Medalist) from Garhwal University. His areas of research interest are condensed matter physics, nanoelectronics, thermoelectric devices, and e-nose application. He received several international fellowships including, the JSPS Fellowship, Japan, from 1997 to 1999, the IFCPAR Fellowship, France, from 2004 to 2005, the BMBF Fellowship, Germany, in 2006, and the CEA Fellowship, France, in 2008..Hee has many awards like Dr. S.K. Date Memorial Lecture Award, Pune University., Science and Technology Excellence Award, Government of Uttarakhand, Memorial Oration Award, Dr. K.V. Rao Scientific Society, HBNI Distinguished Faculty Award to name a few. Dr. D K Aswal has 3 patents granted on his name. 266 Peer reviewed journals, 153 In conference proceeding, 4 edited books and 19 chapters contributed in various books.Dr. D K Aswal has also guided more than 15 PhD. Students. He was a visiting scientist / Honored guest professor / Visiting Professor to various renowned international universities such as University of Paris VII, Diderot, France, Weizmann Institute of Science, Israel, University of South Florida, USA, University of Yamanashi, Japan, and Karlsruhe University, Germany etc. Dr. D K Aswal has conceptualized the production of Indian Certified Reference Materials and secured the first ever trademark of 'Bhartiya Nirdeshak Dravays (BND®) – India Certified Reference materials' in collaboration with Ministry of Commerce. This program enhanced the quality of products and process in the country through production of various reference materials in the fields of water, cement, metals, alloys, petroleum products, coal, food, etc.