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Real-World Analysis of Smart City Integrated Services using High-Speed Network Technologies

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Abstract: Services for smart cities are required to improve productivity, sustainability, and quality of life. They can maximise resource usage, enhance public safety, accelerate economic growth, and promote civic engagement. In the past, cities relied on unreliable and limited-range radio and wired telephone networks. The capabilities of networked city services have significantly increased with the development of technologies like Ethernet and passive optical network (PON). These technologies enable real-time data collecting and analysis by delivering higher data transfer speeds and greater coverage areas. PON connections offer higher bandwidth, greater reliability, and longer lifetimes; 50 Gigabit-PON has the capacity to support different commercial services with notable performance to meet service requirements; and Ethernet networks have lower deployment costs as well as greater flexibility in terms of adding or removing devices. The various use-case scenarios of high-speed network technologies are evaluated. The technology ultimately chosen will be determined by the specific requirements and objectives of the smart city project.

Index Terms: Smart City, GPON, ONU, Fiber-To The-Home, 50G-PON, industrial network, smart factory.

I. INTRODUCTION

More than half of the world's population today resides in cities, which are expanding at an unprecedented rate. City administrations are under growing pressure from this fast urbanization to deliver basic services like transport, healthcare, and energy in an effective and sustainable way. By utilizing high-speed network technology to build an integrated system of services that enhance citizens' quality of life, smart cities provide a potential answer to these problems.

A high-speed network infrastructure that links devices and systems to enable the smooth flow of data and information is at the core of any smart city. Ethernet and fiber optic networks are two of the most often utilized technologies for creating such systems.

The numerous smart city applications along with the suitable networking protocols, bandwidth needs, tolerance for delays, amount of power consumption, reliability requirements, and security requirements.

Using protocols from the personal area network (PAN) class, such as IEEE 802.15.4 (Zigbee) and 801.15.1 (Bluetooth), is possible for applications requiring short range communication, such as smart buildings and smart water networks. These protocols are typically distinguished by a smaller bandwidth, minimal energy use, and short range.

Applications like intelligent transportation, production, and control that need longer ranges need LAN-class protocols, such IEEE 802.11 (WiFi), which are a subset of the LAN family.

For applications like UAVs and the smart grid that require long distance communication, wide area network (WAN) class protocols like IEEE 802.16 (WiMAX), cellular, and satellite can be employed. All of these protocols permit synchronous and asynchronous data connections.

A negligible amount of bandwidth is required by some applications, such as intelligent transportation. Other applications such as UAV, smart buildings, and line monitoring for gas and oil require more bandwidth. Even for the same kind of applications, the amount of bandwidth needs can range from small to moderate or even high based on the generated data. For instance, just a small amount of bandwidth is required for telemetric control and telemetry info, such as UAV surface-to-air control instructions., UAVs relaying images and video to ground-based troops, however, require a significant quantity.

Some applications only tolerate a small amount of end-to-end delay. Intelligent transportation is one instance of such a use. This is the case because the data that is transmitted must arrive within microseconds to allow for control systems to react in time to stop automobile danger or life-threatening crashes. However, additional smart city applications are more forgiving of delays. These include programs that rely on gathering and monitoring data for later analysis. Applications of this type include UAVs that capture photos for subsequent processing.

Power consumption is another important factor for applications used in smart cities; some applications, like smart grid systems, may be able to accept protocols with higher levels of power consumption since they have access to local high-energy resources.

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Medium power requirements apply to other applications that use energy sources with low capacity. Intelligent transportation is one instance of such a use. Because they have a very limited supply of energy resources, other applications need protocols with minimal or very modest energy consumption. UAV, smart water networks, as well as pipeline monitoring are a few examples of these uses.

Another important factor in smart city applications is reliability. Some applications, like smart grids and intelligent transportation, possess severe reliability requirements, while a significant number of applications, such as smart water networks, have the medium reliability requirements.

Most applications require medium to high degrees of security protection. Applications like production control and monitoring, for instance, require medium security, whilst others, like smart grid, require high security because of the data's sensitivity and the importance of the tasks carried out.

II. SMART CITY OVERVIEW

By 2020, Pike Research on Smart Cities predicts that the market for the same would be valued hundreds of billions of dollars, with spending topping $16 billion annually. The synergistic integration of significant industry and service sectors, including intelligent governance, automated transportation, smart utilities, smart buildings, and smart environment, has led to the development of this market.

A. Network Architecture

A smart city's network architecture must be developed to accommodate the numerous devices and applications that will be connected to the network. Because of their high bandwidth and low latency, Ethernet and Fiber Optic technologies are widely employed in city’s infrastructure. Furthermore, because it allows for high-speed data transfer between devices and applications, Ethernet technology is widely used in smart city infrastructure. The employment of these technologies enables efficient and secure data and service transfer over the smart city network.

B. Connectivity

A smart city network's connectivity must be built to enable reliable and secure connectivity for all devices and applications. Fiber optic technology enables high-speed connectivity for various devices and applications at the same time. Furthermore, Ethernet technology provides dependable and secure network connections for apps and devices in smart cities.

C. Security:

The security of a smart city network is critical for protecting against cyber-attacks and ensuring citizens' privacy and safety. Because fiber optic cables are difficult to intercept or tap, they provide secure data transmission across networks.

Ethernet technology also ensures secure data transmission across networks by utilizing multiple security measures to protect against cyber threats.

III. EAL-WORLDUSE-CASES AND APPLICATIONS

A. SimulCity

Through the use of Metro Ethernet accesses and varied traffic sources that would be competing for a finite amount of bandwidth, assessment of the communications effectiveness within a smart city is made possible by the simulation program SimulCity.

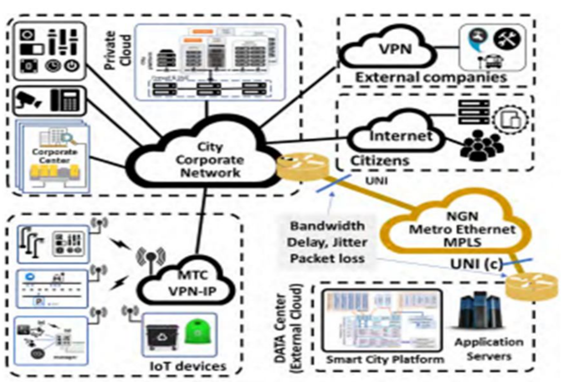

Figure 1 The architecture of a municipal communications system

The major parts and capabilities of the Metro Ethernet User Network Interface (UNI), as illustrated in fig 1, were created to simulate the behavior of a WAN network operator's access interface, including queue management. As with Macrolan Service, three types of traffic were considered: multimedia, gold, and silver.

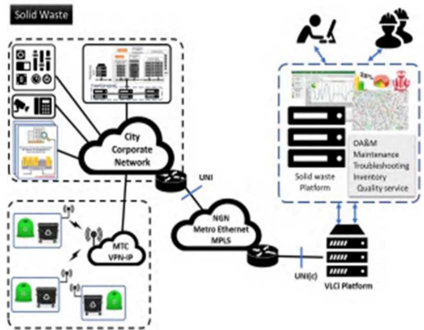

Figure 2 Waste management project communications architecture

Silver traffic is the best effort traffic, gold traffic is video and data in real time traffic, and multimedia traffic is VoIP traffic. While the non-real-time traffic the queue is lengthy (500–1,000 packets) to reduce information loss, the live queue of traffic is short. (10–100 packets) to reduce delays and jitter. The lengths of the queues though can be completely customized by the user. Regarding the SimulCity results, for waste management, as in fig 2, the bandwidth when the traffic distribution is almost homogeneous was quite low, not exceeding 4 Kb/s. Since all containers provides information every two hours, a consistent rate of traffic is achieved by varying the time at which each container conveys its initial information. There is basically no latency because the network is not congested.

B. Fiber-To-The-Home Enhancements

Fiber-To-The-Home (FTTH) is gaining ground in the current search for a dependable broadband connection and high-speed network since conventional broadband connections like DSL and ISDN are struggling to provide users with reliable broadband access due to the emergence of new applications that affect network effectiveness, scalability, consumption of energy, the distance reach, and cost-effective data rates per user.

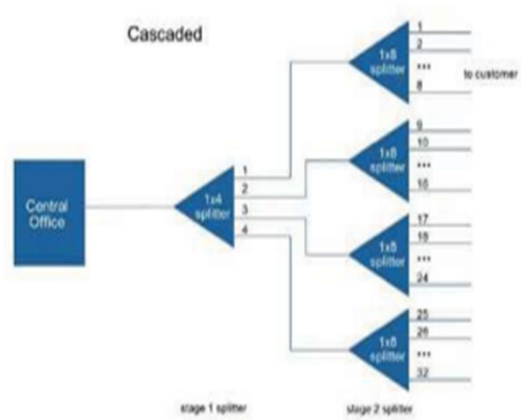

Figure 3 Distributed Split Architecture

The Internet of Things (IoT) has gained significant traction, which has increased the demand for stable broadband connections to support the quick and simple distribution of IoT devices. Due to these issues, new passive optical network device-based designs have been developed to build inexpensive, scalable, long distances, energy-efficient, and fast networks. Figure 3 shows the architecture of the GPON implementation, which uses an individual bidirectional optical fiber expanded by optical amplifiers to cover a total of 64 ONUs. In both directions of the fiber link, optical amplifiers are used. The optical cable was extended to a distance of 50 km using optical amplifiers at data speeds of 2.5 Gbps downstream and 1.25 Gbps upstream.

C. 50GPON in Industrial IoT Networks

To meet the ever-increasing bandwidth needs of broadband access users, particularly for novel purposes outside of traditional residential and corporate access, 50G-PON is being developed. In industrial networks, 50G-PON has novel applications. Utilizing the high-speed capabilities of 50G-PON, these applications support industrial manufacturing, quality assurance evaluation, and smart factory management.

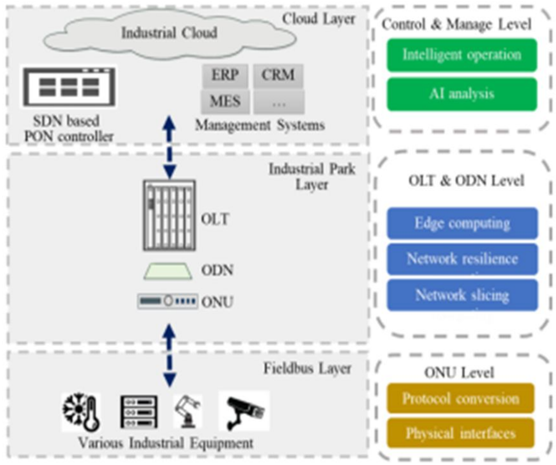

Figure 4 Functional model of 50G PON

The three planes that make up the function plane model for evaluating the application are the fieldbus plane, the industrial park plane, and the cloud plane. Both office subnetworks and field computers and devices send data to the fieldbus plane. The 50G-PON OLTs and ONUs are responsible for the Industrial Park Plane's primary functions. Through a number of industrial physical interfaces, ONUs can communicate with office equipment, in-field equipment, and factory machines. ONUs also translate traditional in-field management protocols, including Transaction Language 1 (TL1), into the 50G-PON protocol. The OLT carries out increasingly complex tasks to enhance industrial network services. The OLT manages data encryption and registration authentication for network transmission security.

The OLT monitors manufacturing processes and provides real-time data to enhance product quality and identify production errors. By segregating resources for different services, OLT also facilitates network slicing. As a result, function-oriented virtualized sub-networks that serve numerous purposes can be multiplexed on the same physical industrial network. Finally, the OLT configures ONUs to offer network security. When the industrial network fails, this function ensures that company operations continue uninterrupted as seen in Fig. 5.

Using the reliable functions provided by both the fieldbus plane and the industrial park plane, the cloud plane manages and runs the whole industrial network. The cloud plane has to work sensibly at all times. The transition of resources into goods and services is controlled by the cloud plane. It is in charge of quality control, manufacturing oversight, and business planning. Analysing AI has a crucial role, too. The industrial park plane multiplexes enormous volumes of data from industrial facilities, while the cloud plane pulls information for automating the process of evaluating client demands, product competence, supply chain challenges, company earnings, and potential customer analysis. Tested line rates at both the downstream and upstream physical interfaces are 49.7 Gb/s and 24.8 Gb/s, respectively, without taking into account the overhead provided by 50G-PON and industrial protocols such FEC parity, frame header, and frame trailer. The testbed's highest download and uplink service throughputs are respectively 15.9 Gb/s and 39.9 Gb/s.

IV. CONCLUSION

The 50G-PON can enable various industrial services with remarkable performance to satisfy service requirements, and the GPON employing FTTH demonstrated the fact that downstream and upstream throughput were optimized, whereas Ethernet provided greater flexibility in the design of various smart city project services. The conclusion may be reached that there is a need for a holistic approach to creating a smart city integrated services system that takes into account not only network technology but also other system components such as data analytics and intelligent automation. Such an approach would assist ensure that smart city projects succeed in improving citizens' quality of life and encouraging sustainable urban development.

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