Introducing IoT to Big Data Platform for Network Performance Monitoring

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Abstract—**Telecommunication operators are collecting large amounts of data for various purposes such as network performance monitoring, network planning, better customer support, etc. Nowadays, big data technologies are commonly used to couple with enormous amounts of data. Thus, telecommunication operators use big data platforms to process and store data collected from their networks. Data are collected from the network and user devices. Since network operators cover most of the residential users, it is possible to use this access to introduce IoT (Internet of Things) and smart city support. By extending the already existing big data platforms to support IoT devices placed at network users' premises, smooth integration of various IoT devices with the smart city concept can be achieved. Such integration would have significant benefits for network operators, users and local communities. In this paper, we propose an extension that introduces IoT support to the existing big data platform used for HFC (Hybrid Fiber-Coaxial) network monitoring. An overview of the most attractive IoT use cases that can benefit from the proposed extension is also presented in the paper.**

Index Terms—**Big data, IoT, Smart city, Smart home, HFC network.**

I. Introduction

Telecommunication operators typically serve large number of users. In order to successfully perform such task, operators use very complex and heterogeneous telecommunication networks which need to be constantly monitored. For monitoring purposes, operators collect and store data from numerous network devices [1,2]. By processing the collected data, it is possible to achieve optimal network performance and provide high QoS (Quality of Service) to users. Since the amount of collected data is enormous, big data technologies need to be used to efficiently store and process such amount of data [3].

Smart home and smart city are IoT concepts that are becoming very popular nowadays [4,5]. Given the large number of residents and the fact that each user will typically have multiple IoT devices and sensors at home, it is obvious that amount of data collected can be very large. Thus, big data technologies would provide excellent solution for storing and processing such amounts of data [6]. Most of the residential users are covered by some telecommunication operator (HFC, passive optical network (PON), etc.) and the operators use big data platforms to store and process data collected from their networks. Given that fact, these big data platforms can be extended to collect and store data from IoT devices and sensors placed at user premises. In this way, same infrastructure could be reused for IoT purposes. By integrating existing telecom operators big data platform in smart city environment, highly economic and efficient smart city solution can be achieved.

In [7], big data platform for HFC network monitoring is extended with support for efficient failure detection and localization. In this paper, we propose extension of this big data platform to support IoT devices at users' premises. It will be shown, that such extension does not require architecture modifications in the already existing big data platform. Only, adjustments in data collection layer need to be done. Once data are collected and stored, it is up to data consumers (smart city solutions and applications, users, operators) to determine which types of processing of the collected data need to be supported. For example, application for users that graphically shows measured values from their sensors, or notification in case of threshold violation (e.g. smoke detectors detect fire). In this paper, we also present the most attractive use cases that would benefit from such IoT extension of big data platform.

Remainder of the paper is organized as follows. In section II, we give related work overview. Section III presents the existing big data platform for HFC network monitoring, and the introduced extensions to support data collection and storage from IoT devices. Section IV contains a survey of use cases that would benefit from the IoT extension of the big data platform introduced in section III. Finally, section V concludes the paper.

II. Related Work

IoT based smart home solutions represent one of the most important IoT markets since they offer a huge variety of different applications for enhancements of resident’s quality of life. It is possible to install different devices for monitoring of various activities. The monitoring can be focused on the resident’s activities and on the different parameters in the home. In the elderly healthcare solution, different medical sensors are provided in form of smart bracelets and other wearable devices [8], that allow efficient monitoring of movements and condition of a patient. Different sensors for environmental monitoring could be installed like sensors for temperature, relative humidity, light intensity measurements,

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fire/smoke detectors, etc. Based on these measurements, temperature and lighting control can be automatized and appropriate alarms can be raised. Monitoring of energy and water consumption, and water leakage detection can be achieved with appropriate sensors. Also, different appliances in home can be remotely monitored, such as sensors for audio and video surveillance, motion detection that are typically installed to increase home safety [9].

Within the smart cities many urban related problems are aimed to be solved such as air pollution, urban noise monitoring, traffic jams, smart parking, energy consumption, waste management, smart infrastructure, street lighting, assistance to senior citizens, etc [10]. This includes different types of technologies (big data, IoT, WSN (Wireless Sensors Networks) and cloud. Particularly interesting elements for planning Wi-Fi networks in large cities are presented in the paper [11]. Wi-Fi as a transmission technology is preferable in many smart city applications since it provides connectivity to smart phones, computers and many wearable gadgets. Different challenges of Smart City IoT system deployment are addressed in [4], where Security and Privacy, Smart Sensors, Networking and Big Data Analytics are recognized as the most important ones.

IoT concept is one of the most important trends in telecommunications. IoT is integral part of many "smart" solutions like smart city, smart buildings, smart agriculture, smart transport, smart healthcare... [12]. Given the significant amount of data that IoT systems generate, big data is recognized as a "key enabling technology for IoT" [12]. For this reason there are numerous papers that deal with IoT and Big Data combination. Surveys on big data in IoT can be found in [12,13]. A large number of papers on the topic of smart city shows that this concept is one of the most popular ones from the IoT area. Survey on big data in smart city solutions is given in [14]. Industry also embraced IoT concept because digitalization of industrial processes increases efficiency [15]. In [15], Industrial Big Data as a result of IoT adoption in manufacturing is discussed. Big data and IoT in smart farming are discussed in [16]. Although, many IoT solutions are already operating along with big data technologies support, there are still some open challenges. Survey on these open challenges is given in [17].

III. BIG DATA PLATFORM ARCHITECTURE

In this section, first we give a brief description of the existing big data platform architecture for HFC network performance monitoring. Then, we describe extensions necessary to introduce IoT in the existing big data platform.

Fig. 1 shows the big data platform architecture for performance monitoring of HFC network. Big data platform comprises two major parts - big data cluster and data collection layer. Big data cluster uses several big data tools to store and process collected data. The used big data tools include OpenTSDB (Open Time Series Database), Apache HBase, HDFS (Hadoop Distributed File System), Apache Spark, Hadoop YARN (Yet Another Resource Negotiator), and Zookeeper. OpenTSDB is used to verify and process incoming messages from data collection layer, and to store these messages in HBase tables. HBase writes table files to HDFS while HDFS is responsible for storing data on physical storage units. Apache Spark is necessary for data aggregations. Hadoop YARN is used to allocate resources to jobs. YARN also enables different processing frameworks to use common hardware. Zookeeper synchronizes distributed services.

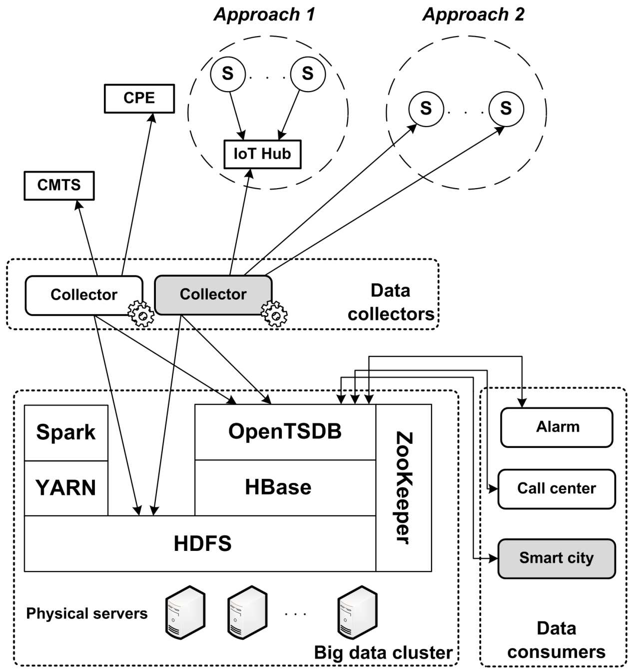

Fig. 1. Big data platform with added support for IoT devices

Data collection layer is responsible for collecting data from CMTS (Cable Modem Termination System) and CPE (Customer Premises Equipment) devices in HFC networks as they represent network devices with a possibility to collect data from them. CPE devices include cable modems and set-top boxes. SNMP (Simple Network Management Protocol) is used for data collection. There are numerous data collectors working in parallel in the data collection layer due to large number of devices in the HFC network from which data need to be collected. Various data (metrics) are collected from CMTS and CPE devices, while the data collection period depends on the data type and importance. Collection period is set in range from 1 minute to 1 hour depending on the importance of collected metrics. Collected data are sent to OpenTSDB via web socket and in parallel data are also written to HDFS.

Fig. 1 also shows the extensions necessary to accommodate IoT support. The updated or added modules are marked with grey coloring. Main update needs to be made in data collection layer. Namely, data collectors need to be aware of new devices and data types that need to be collected. The advantage of the previously described big data platform is its flexibility. Due to large number of different network devices (different vendors, versions, models, etc.), big data platform was developed to efficiently couple with variety challenge

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that is typical for big data usage [18]. This means that the data collectors are designed to be flexible and adjustable to new devices added to monitored HFC network. Obviously, IoT devices also represent new devices from the data collector point of view. Thus, adding a support for new devices is not a complex task.

The other extension is connection to new data consumers. In the case of IoT introduction that would be IoT data consumers, e.g. smart city environment as shown in Fig. 1. These IoT data consumers can be internal or external depending on the type of integration of the big data platform. For example, the big data platform besides the network monitoring system can serve also as IoT service hub operated by the network operator (internal data consumer). But, the big data platform can provide access to data to external data consumers such as local government smart city platform or external companies like distributors of electricity, water or gas.

At user premises, there are two possible approaches that affect the data collector extension for IoT devices support. One approach is to collect data directly from each IoT device. Second approach is to have a hub for all IoT devices at user premises. In this second case, data collector connects only to a hub which reduces the number of connections necessary to collect all IoT related data from user premises. The other advantage of the hub approach is simplified addition of support for IoT data in data collection layer. Namely, in this case focus is only on the types of IoT metrics not the types of IoT devices. Secondly, this gives more freedom for connecting IoT devices to central hub at home (for example, ZigBee or Bluetooth). Thirdly, if WiFi is used to connect IoT devices to central hub, a central hub might be integrated to cable modem as nowadays these modems typically have WiFi capabilities. Both approaches are illustrated in Fig. 1.

IV. USE CASES

The proposed IoT support extension of the big data platform for HFC network performance monitoring can be applied in many smart monitoring IoT based use cases. IoT and sensor networks represent sources of time series data that can be collected, stored and processed by the proposed extension of big data platform. As discussed in the previous section there are two approaches that can be used to collect data from IoT devices - direct and indirect over IoT hub. Note that these two approaches can coexist if necessary.

Some of the most important and common IoT based smart metering in homes are: indoor air quality monitoring, energy consumption and water consumption monitoring. These metering devices produce periodic and relatively small packet traffic. The most common indoor air quality monitoring parameters are CO, CO_2, PM (Particle matters), VoC (Volatile compounds), temperature and relative humidity. Additionally, some devices support O_2, CH_4, H_2S, NH_3 as well. There are a lot of already available low-cost devices for this purpose [19]. These devices can be used for air quality monitoring and fire detection. Normally, reporting period is set to 5 minutes, but for the alarm purposes it could be set to 1 minute. Expected payload is 0.5 kB per sampling interval. In the case of 1 minute monitoring period, expected data volume per one device would be 720 kB per day, i.e. 21.6 MB per month. If data collectors enrich the collected data with additional information (user id, device model/type,...), the expected data volume can be a bit larger. The required storage space for data collected over one month would be around 5.7 TB under following assumptions: each home has 2 IoT devices in average; data collected from each IoT device requires 30MB per month in average; there are 100000 homes covered by HFC network.

Telecom operators can allow access to the raw data via API (Application Programming Interface). But more attractive for their clients would be aggregation, processing and visualization of their data available via web portal where clients can easily follow the measurements and set alarms and/or notifications, calculate air quality index, etc. In case of different models and versions of IoT devices, operators can perform data aggregations per manufacturer or model to gain insight in the performance of the devices and determine which devices are more preferable and offer them to their clients in future deals. In case of air quality measurement devices, outside units can be mounted as well, for example, on balconies. Data collected from such devices can be aggregated and processed to gain deeper insight in air quality in different parts of the city, or on different height levels in case of multi-storey buildings. This information can be very important for local communities to detect critical zones.

While air quality monitoring requires quite frequent reporting, energy [20] and water [21] consumption can be reported once per day (about 0.4 kB per measurement in both cases, which means 12 kB per month). Energy module collects data about power consumption and other electric parameters, while the water consumption sensor monitors amount of water usage in the home. Measurements can be collected by the platform, where data are stored and processed. The measurements can be presented in form of graphs, and when data reach the specified level of power or water consumption, alerts can be generated and sent to the user. Also, smart city concept assumes interconnection of citizens, local governments and utility companies. Utility companies need to read measurement devices to check the consumption by their clients. If the readings of these devices are integrated with the big data platform, then that data can be passed to utility companies. In this way, multiple benefits can be achieved. Automatized and remote measurement readings, detection of anomalies which can trigger alarm to both utility companies and users. In case of multi-storey buildings, utility measurement devices are typically not part of the homes. In such cases, if the building is covered by HFC network, additional cable modem can be installed that would cover only the utility measurement devices as a part of agreement between the users, operator and utility companies. This actually perfectly represents the idea and aim of smart city concept.

As already explained, presented use cases are not very demanding in terms of storage capacity, so big data platform should be able to easily handle a lot of users. Insight into collected measurements provides to users powerful information how to optimize water and power consumption and how to improve the air quality. Proposed concept facilitates smart home integration and could be expanded for the smart city measurements integration with goal to create pollution and noise maps (devices can be also mounted outside for outdoor air quality monitoring), remote reading of electricity and water consumption, thus, optimizing the work of communal services. On the other hand, the proposed expansion provides an excellent opportunity for the operators to expand their service portfolio and offer new smart services to their users, which would bring a new revenue and increase users' confidence and satisfaction.

The described IoT devices are low-cost and easy for installation and handling. Of course there are a lot of other sensors and devices that could be installed for monitoring of different kinds of parameters, and in this section we presented a few useful examples for the proof of concept purposes.

V. Conclusions

In this paper we propose extension for IoT support of existing HFC network performance platform based on big data technologies. The proposed extension is incremental and not complex, and most importantly does not affect the original purpose (performance monitoring) of the big data platform. The presented use cases that would be enabled by the proposed extension show that significant benefit would be gained by all the parties involved: users, operators, utility companies, local communities. This is exactly in line with the smart city ideas and goals. As a part of our future work, we will focus on tight integration of the proposed extension to smart city solutions with special emphasis on air and noise pollution tracking and creating corresponding noise and pollution maps.

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References

[1] Y. He, F. R. Yu, N. Zhao, H. Yin, H. Yao, R. C. Qiu, “Big Data Analytics in Mobile Cellular Networks,” *IEEE Access*, vol. 4, pp. 1985-1996, Mar. 2016.

[2] A. J. Garcia, M. Toril, P. Oliver, S. Luna-Ramirez, R. Garcia, “Big Data Analytics for Automated QoE Management in Mobile Networks,” *IEEE Communications Magazine*, vol. 57, no. 8, pp. 91-97, August 2019.

[3] M. Simaković, Z. Cica, I. Masnikosa, “Big Data Architecture for Mobile Network Operators,” in *proc. of TELSIKS 2021*, Nis, Serbia, Oct. 2021.

[4] A. S. Syed, D. Sierra-Sosa, A. Kumar, A. Elmaghraby, “IoT in Smart Cities: A Survey of Technologies, Practices and Challenges,” *Smart Cities*, vol. 4, no. 2, pp. 429–475, Mar. 2021.

[5] A. Nag, M.E.E. Alahi, N. Afsarimanesh, S. Prabhu, S.C. Mukhopadhyay, “IoT for smart homes”, in book *Sensors in the Age of the Internet of Things: Technologies and applications*, pp. 171-199, 2019.

[6] S. Khare, M. Totaro, “Big Data in IoT,” in *proc. of ICCCNT 2019*, Kanpur, India, Jul. 2019.

[7] M. Simakovic, Z. Cica, “Detection and Localization of Failures in Hybrid Fiber–Coaxial Network Using Big Data Platform,” *MDPI Electronics*, vol.10, no.23, November 2021.

[8] B.J. Cheng, M.M.A. Jamil, R. Ambar, M.H.A. Wahab, A.A. Ma’radzi, “Elderly Care Monitoring System with IoT Application”, in book *Recent Advances in Intelligent Information Systems and Applied Mathematics*, pp. 525-537, 2020.

[9] M.R. Alam, M.B.I. Reaz, M.A.M. Ali, “A Review of Smart Homes—Past, Present, and Future,” *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, vol. 42, no. 6, pp. 1190-1203, Nov. 2012.

[10] J. Temperton, “Bristol is making a Smart City for Actual Humans”. Wired, 17 March 2015. http://www.wired.co.uk/news/archive/2015-03/17/bristol-smart-city.

[11] L. Zhang, L. Zhao, Z. Wang, J. Liu, “WiFi Networks in Metropolises: From Access Point and User Perspectives,” *IEEE Communications Magazine*, vol. 55, no. 5, pp. 42-48, May 2017

[12] M. Bansal, I. Chana, S. Clarke, “A Survey on IoT Big Data: Current Status, 13 V’s Challenges, and Future Directions,” *ACM Computing Surveys*, vol.53, no.6, pp. 1-59, Nov. 2021.

[13] E. Ahmed et al., “The role of big data analytics in Internet of Things,” *Computer Networks*, vol. 129, no. 2, pp. 459-471, Dec. 2017.

[14] I.A.T. Hashem et al., “The role of big data in smart city,” *International Journal of Information Management*, vol. 36, no. 5, pp. 748-758, Oct. 2016.

[15] D. Mourtzis, E. Vlachou, N. Milas, “Industrial Big Data as a Result of IoT Adoption in Manufacturing,” *Procedia CIRP*, vol. 55, pp. 290-295, 2016.

[16] N. N. Misra, Y. Dixit, A. Al-Mallahi, M. S. Bhullar, R. Upadhyay, A. Martynenko, “IoT, big data and artificial intelligence in agriculture and food industry,” *IEEE Internet of Things Journal*, pp. 1-1, May 2020.

[17] S. Kumar, P. Tiwari, M. Zymbler, “Internet of Things is a revolutionary approach for future technology enhancement: a review,” *Journal of Big Data*, vol. 6, no. 1, pp. 1-21, Dec. 2019.

[18] M. Simakovic, Z. Cica, “Big Data Applications and Challenges,” in *proc. of Infoteh 2016*, Jahorina, BiH, Mar. 2016.

[19] https://www.renkeer.com/product/aqi-sensor/

[20] https://www.acrel.co.id/product/Wireless_energy_meter/IoT_Wireless_energy_meter.html?gclid=Cj0KCQjw5-WRBhCKARIsAAId9FlVSq3lp8SpBQ6TC09F9covmEei2ZZF9_tGw6zH6NRKM8NIb4L8WLMaAj90EALw_wcB

[21] Z.H. Che Soh, M.S. Shafie, M.A. Shafie, S.N. Sulaiman, M.N. Ibrahim, S.A.C. Abdullah, “IoT Water Consumption Monitoring & Alert System,” in *proc. of ICELTICs 2018*, Banda Aceh, Indonesia, Sep. 2018.