**ENN524 Mobile Network Engineering**

**Assignment 1: Comparative study of wireless networks and network planning**

**Distribution Date**: 5 /08/2024 (Week 3).

**Due Date**: 11:59 pm 09/09/2024 (end of Week 7)

**Total Raw Marks**: 15 (worth 15%)

**All questions must be completed and submitted individually.**

Question 1.1 (3 marks). This is a review question that requires you to compare and analyze the characteristics of specific WPAN (Wireless Personal Area Network) and WLAN (Wireless Local Area Network) technologies. You should refer to your course lecture notes and relevant literature to gather information for your analysis. Some questions may not have definitive answers, so please provide the best information you can find. Full marks will be awarded for correct answers above 85%. Please fill out Table 1 provided below.

Question 1.1

(You can use additional pages or landscape your page if necessary for completion)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Bluetooth | IEEE 802.11b | IEEE 802.11g | IEEE 802.11n | IEEE 802.11ac | IEEE 802.11ax |
| Standards | Bluetooth | IEEE 802.11b | IEEE 802.11g | IEEE 802.11n | IEEE 802.11ac | IEEE 802.11ax |
| Communication range | < 30m | 35m indoor/ 140m outdoor | 38m/ 140m | 70m/ 250m | 35 indoor,  150~300 feet | 30m/ 120m |
| Frequency band/channels | 2.4 GHz ISM band | 2.4 GHz, | 2.4 GHz, | 2.4 GHz,  5 GHz, | 5 GHz,  80 and 160 MHz channels | 2.4 GHz,  5 GHz,  6 GHz |
| Peak data rate | 50 Mbps | 11 Mbps | 54 Mbps | 600 Mbps,  150 Mbps (multiple antennas for single-stream speeds) | 6.93 Gbps | 10.53 Gbps |
| Power saving mode | BLE | Power Save Mode (PSM) | PSM | Power Save Multi-Poll (PSMP) | PSMP | Target Wake Time (TWT) |
| Modulation techniques | GFSK | DBPSK/  DQPSK (CCK coding) | DBPSK/DQPSK | DBPSK/  QPSK/16-QAM/64-QAM/ | DBPSK/  QPSK/16-QAM/64-QAM/  256-QAM | OFDMA, 1024-QAM |
| Spatial streams |  | 1 | 1 | ~4 | ~8 | ~8 |
| Single AP capacity |  | ~32 clients | ~32 | ~60 | ~100 | ~256 |
| Components | Transceiver, baseband, protocol stack, antenna | Wifi-transceiver,  antenna | Wifi-transceiver,  antenna | Wifi-transceiver,  Antenna (MIMO support) | Wifi-transceiver,  Antenna (MIMO, MU-MIMO support) | Wifi-transceiver,  Antenna (MIMO, MU-MIMO, OFDMA support) |
| Energy consumption | Low, less than 30 mA | Moderate, | M | M~H | Higher | Higher |
| Network mode | Point-to-Point,  Broadcast,  Mesh | Infrastructure, ad-hoc | Infrastructure, ad-hoc | Infrastructure, ad-hoc | Infrastructure | Infrastructure |
| Distance | Up to 100 | M | M | Extended | Extended, Faster speeds over shorter dis. | Improved range and performance in high-density environment |
| Security | 64b/128b,  user defined application layer | WEP, WPA | WEP, WPA, WPA2 | WPA2 | WPA2,  WPA3 | WPA3 |
| Mobility of end-devices | High | Medium | M | M~H | H | H |
| Applications (examples) | Wireless headphones, speakers, wearables,  IoT devices | Home Wi-Fi networks, basic internet browsing | Multimedia streaming | HD video streaming, online gaming,  Enterprise networks | 4K video streaming,  Enterprise app., IoT | Smart homes,  Enterprise networks,  AR/ VR |

Question 1.2 (3 marks). This question involves reviewing and comparing the characteristics of selected LPWPAN (Low Power Wireless Personal Area Network) technologies. You are required to refer to your course lecture notes and relevant literature for information. Some questions may not have definitive answers, so provide the best information available. Full marks will be awarded for correct answers above 85%. Fill out Table 2 provided below.

This is a review type of question. Review and compare the characteristics of selected LPWPAN

Question 1.2 Complete the following table *[use additional pages or landscape your page as required].*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Lora | Zigbee | Sigfox | IEEE 802.11ah | LTE-M | NB-IoT |
| Standards | LoRaWAN | IEEE 802.15.4 | Sigfox | IEEE 802.11ah | LTE-M | NB-IoT |
| Communication range | M/H, 2-15 km (urban), up to 50 km (rural) | 10-100m | 10-50 km (urban), up to 1,000 km (rural) | 1 km (indoor), up to 5 km (outdoor) | 10-15 km | 10-15km |
| Frequency band/channels | Unlicensed ISM bands | 2.4GHz,  Sub 1GHz | Unlicensed ISM bands | Sub-1 GHz ( 900 MHz) | Licensed LTE bands | Licensed LTE bands |
| Data rate | 50kbps | 20, 40, 250 kbps | 100 bps (uplink), 600 bps (downlink) | 347 Mbps | 375kbps – 1Mbps | Up to 250 kbps (uplink), 20-250 kbps (downlink) |
| Data latency | 10s | Low-Moderate | 10s | Low | L - M | L - M |
| Modulation techniques | Chirp Spread Spectrum (CSS) | DSSS (Direct Sequence Spread Spectrum) | DBPSK (Differential Binary Phase Shift Keying) | OFDM, BPSK, QPSK, 16-QAM, 64-QAM | QPSK, 16-QAM | BPSK, QPSK |
| Spatial streams |  |  |  | 1-4 |  |  |
| Nodes per BS/AP/Gateway | ~100,000 /gateway | ~65,000 nodes /network | Millions of devices per gateway | ~8,191 /AP | ~10,000 /base station | ~ 100,000 /base station |
| Components | LoRa transceiver, antenna | Zigbee transceiver, antenna | Sigfox transceiver, antenna | Wi-Fi HaLow transceiver, antenna | LTE-M modem, antenna | NB – IoT modem, antenna |
| Energy consumption | Low | Low | Ultra-low | Low | M | L |
| Network topology | Star, WAN | Mesh, star, tree | Star/WAN | Star, mesh | Star | Star |
| Security | AES-128 encryption | AES-128 encryption | AES-128 encryption | WPA3 | LTE encryption | LTE encryption |
| AP/BS/Gateway capacity | High | Moderate | Very high | High | H | Very High |
| Mobility of end-devices | Low | Moderate | Low | M - H | H | L |
| Preamble/Leader sequence length | 8-12 symbols | 4-6 bytes | 4 bytes | 14 OFDM symbols | 10 ms | 5 ms |
| Dedicated network | Yes | Yes | Yes | Yes | No | No |

**Question 1.3 Call For Proposals: open mine dynamic situation monitoring (9) Marks)**

This assignment aims to provide a comprehensive understanding of network planning through research, system analysis, and system planning. Your task is to submit a formal proposal in response to a Call for Proposals from ABC Mining, an open mine company seeking to monitor the dynamic situation of the open mine walls and tailing dam using geotechnical, pressure and displacement sensor sets. The company has provided a map of the mine site where around 60 sensor sets can be evenly installed on the walls and dam. The data message size for each sensor set ranges from 3 to 10 kilobits (kb) (each sensor set transmits data that ranges in size from 3 to 10 kilobits) per message. and the transmission rates from 1 to 15 minute per message. Your assignment project is to design a cost-effective automated IoT monitoring system for ABC Mining based on this scenario.

The entire mine site spans about 3x2 squared kilometres. Your proposal should provide ABC Mining's network service provider with a detailed plan to build the monitoring system. You are required to write up your proposal with about 800 words and list your references. The key aspects to consider in your proposal include:

1. Two possible network solutions based on Wifi-Halow or LoraWAN and NB-IoT respectively, considering the hardware and operational costs of wireless units (wireless modules, Microcomputer unit, gateway/AP for device-network connectivity). Compare the costs and performance of both solutions and select one solution as your proposal and justify the reason for the selected solution.
2. The architecture and topology of the selected network solutions, as well as other components on the site that need to be served
3. Proposal for the edge or cloud computing platform in the monitoring system
4. Security planning and recommendations
5. Summary of the proposal.

Your proposal should address these aspects in detail, providing ABC Mining with a clear roadmap for implementing the monitoring system.

You are required to write up your proposal with about 800 words (2 pages), plus a list of references

**Proposal**



**LoraWAN**

**Sensors (tier1)**

Around 60 sensors (geotechnical, pressure, displacement)

**Gateways (tier2)**

Wifx L1

**Server (tier3)**

AWS IoT Core for LoRaWAN

**Security**

Session key (Enhancing the Security of the IoT LoraWAN Architecture, 2016)

**Proposal**

To meet the client's monitoring requirements for the open mine walls and tailing dam, a total of 60 geotechnical sensors (such as crackmeters, string gauges, and weather stations), pressure sensors (such as LoRaWAN ATEX Pressure Sensor), and displacement sensors (such as LEDT) must be implemented separately as the first tier of the LoraWAN architecture. After receiving data from the sensors, three to four of LoraWAN gateways (i.e. Wifx L1) are ideal for passing that data to the cloud server (i.e. AWS IoT Core for LoraWAN), converting RF signals to an efficiency format. LoraWan is sufficient to support the client’s requirement regarding sensor message transmitting rate: 3 to 10 kb, because LoraWan supports 50 kb/s, which means to transmit a message only needs 0.06 seconds to 0.2 seconds (time to transmit = 3 kilobits -50 Kb/s = 0.06 seconds, 10 kilobits -50 Kb/s = 0.02 seconds).

In terms of integrating most functions within the network, it is important to set up a common cloud server, such as AWS IoT Core for LoRaWAN. Through the subscription function of MQTT on the cloud server, the collected data can be sent to the clients’ devices and controlled remotely, or further functions like data analytics.

However, LoRaWan utilizes an unlicensed band, which presents challenges in terms of security. To address this gap and prevent hackers from getting encrypted information while exchanging between sensors and the server, using a session key that is changed in every session could be a solution (Enhancing the Security of the IoT LoraWAN Architecture, 2016).

Additionally, managing the power consumption for the whole IoT architecture plays an important role in ensuring its cost and efficiency since they are connecting as many as 60 sensors within the network. Because of this, the devices' power and energy use directly mirror the power use of the IoT devices they control (Dibal et al., 2023). Sensor scheduling/duty cycling, which allows the sensors to sleep and wake up periodically, and adaptive sampling, which reduces the sampling rate of sensors (Khalifa & Moid, 2024), are the relevant solutions.

**NB- IoT**

**Sensors**

Dragino NSPH01, DUS2-N-B-10m-C5-X-I

**Gateways**

M1200-4M

**Server**

AWS IoT Greengrass for local, AWS EC2 for cloud control over the server infrastructure

**Security**

SHA-256 hash algorithm (Darghmi et al., 2022)

**Proposal**

A total of 60 sensors (i.e. Dragino NSPH0, DUS2-N-B-10m-C5-X-I) will be used by the system. Because these monitors do not use much power and even support multiple communication protocols (UDP, LwM2M, MQTT, NIDD, etc.), they are perfect for mining operations that are far away and need long battery lives. NB-IoT lets these sensors send small amounts of data over long distances quickly and efficiently. This makes connection reliable even in tough places like open mines.

Through M1200-4M gateways, data from the devices will be sent to the network. NB-IoT gateways like the M1200-4M are made to offer stable connectivity, giving more coverage in remote areas, and reducing the chance of data loss. They also allow contact in both directions, so not only can data be collected, but commands can be sent from the server to the sensors as well.

For controlling the server infrastructure, the system will use both AWS IoT Greengrass and AWS EC2. Greengrass will be used for local control, and EC2 will be used for management in the cloud. Edge computing is made possible by AWS IoT Greengrass, which lets data processing and machine learning models run locally. This cuts down on latency and improves business efficiency. This setup is great for watching and controlling things at the mine site in real time without always needing to connect to the cloud. AWS EC2 will be in charge of cloud control, which will allow the IoT system to grow and be managed from one place. This mixed design allows for adaptability in processing, storing, and analysing data, so important tasks can still be carried out even if there is a temporary loss of connection to the cloud.

The SHA-256 hash algorithm will be used for safe data encryption to protect the integrity and privacy of the data. According to Darghmi et al. (2022), this method is a well-known cryptographic hash function that protects strongly against changes and unauthorised access. By using SHA-256, the system makes sure that all data sent between sensors, gateways, and computers is encrypted and cannot be read or changed by anyone else.

**Summary**

Both LoraWan and NB-IoT provide efficient and secure methods for monitoring open mine walls and tailing dams, with LoRaWAN being cost-effective and ideal for low-bandwidth, low-power applications, while NB-IoT offers more reliable communication over longer distances with better coverage in open-mine environments. The LoRaWAN system leverages a cloud-based architecture with MQTT for real-time control and analytics, while NB-IoT incorporates edge computing with AWS IoT Greengrass for improved local processing. Security is a priority in both systems, with LoRaWAN using dynamic session keys and NB-IoT implementing SHA-256 hash algorithm encryption. Furthermore, in terms of emerging saving, minimising the power consumption is recommended for both network considering the networks are implemented in an open-pit mining and/ or a surface mining environment.

**Reference**

Darghmi, E., Daraghmi, Y., Daraghma, R., Fouchal, H., & Ayaida, M. (2022). A Blockchain framework for Enhancing NB-IoT Security and Authentication: Health Monitoring System as a case. *TELEMATIQUE*, *21*(1). <https://www.researchgate.net/publication/377188770_A_Blockchain_framework_for_Enhancing_NB->

Dibal, P., Onwuka, E., Zubair, S., Nwankwo, E., Okoh, S., Salihu, B. A., & Mustaphab, H. (2023). Processor power and energy consumption estimation techniques in IoT applications: A review. *Internet of Things*, *21*, 100655. <https://doi.org/10.1016/j.iot.2022.100655>

Engineering, O. (2021, July 31). *What is a Linear Variable Differential Transformer?* https://www.omega.com/en-us/. <https://www.omega.com/en-us/resources/lvdt-sensors#:~:text=Variable%20Differential%20Transformer%3F-,What%20is%20a%20Linear%20Variable%20Differential%20Transformer%3F,electric%20signals%2C%20and%20the%20reverse>.

*Enhancing the security of the IoT LoraWAN architecture*. (2016, November 1). IEEE Conference Publication | IEEE Xplore.

<https://ieeexplore.ieee.org/abstract/document/7842904?casa_token=stMda-eK94MAAAAA:KYB3APisyafs1Ab5K-uKCsgB5ob2DPPmCqzo-lOCEDrZyoev5piglsSAUAHKBZo2ZphHBCNUKA>

Khalifa, S., & Sandhu, M. (2024, August 30). Energy efficiency in IoT [Lecture slides]. IFN649 Lecture, Queensland University of Technology.

*LoRaWAN ATEX Pressure Sensor Specifications | SENSA.iO*. (2024, April 22). SENSA.iO. <https://sensa.io/lorawan-atex-pressure-sensor/>

*Study Case in Mining Industry: Monitoring Rollers using Embedded LoRaWan*. (2021, May 17). IEEE Conference Publication | IEEE Xplore.

<https://ieeexplore.ieee.org/abstract/document/9459901?casa_token=eAnQqANzw-kAAAAA:8L1JVHlAQeM4Dvp6NPWbPNcFaRTLL7U60fOdRdMb_9_w2bMwWpRBCqlWcf_IuEogbD8ovMUkQg>

Trimble Monitoring. (2023, May 17). *Geotechnical Sensors Basics* [Video]. YouTube. <https://www.youtube.com/watch?v=uirVSURwppo>

*Wireless Monitoring of Environmental Parameters for Underground Mining using Internet of Things with LoRa Transceiver Module*. (2022, December 1). IEEE Conference Publication | IEEE Xplore. <https://ieeexplore.ieee.org/abstract/document/10054280?casa_token=He9_6jzWzL8AAAAA:jI5osG-9wIv_z1S0O_k7Mv-Z4b6SEEcwSO7hvohancEAcvk6NM2p7IJljXW_FC3O7J9XC0c-5A>