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A Survey on Wireless Networks used in IoT Applications

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ABSTRACT: The rise of connected devices has placed an emphasis on efficient usage of wireless communication. The need for connecting simple devices like sensors and actuators is rapidly increasing. There are a lot of technologies emerging that are intended to connect low cost, low power, and low bandwidth devices. This paper aims at explaining the subtle differences between the various types of networks. Here, we attempt to classify networks based on their power.

KEYWORDS: wireless network; power; Internet of Things (IoT); bandwidth; costs

I. INTRODUCTION

Networks can be classified into various types based in different criteria. Based on power, networks can be divided into mainly two categories: Low Power Networks and High Power Networks.

II. RELATED WORK

A. Power and dBm Calculations

RF power is most commonly expressed and measured in decibels with a milliwatt reference, or dBm. A decibel is a logarithmic unit that is a ratio of the power of the system to some reference. A decibel value of 0 is equivalent to a ratio of 1. Decibel-milliwatt is the output power in decibels referenced to 1 mW.

Conversion between mW and dBm can be done using the following formulas:
P(dBm) = 10 · log10(P(mW))
P(mW) = 10(P(dBm)/10)

Path loss is the reduction in power density that occurs as a radio wave propagates over a distance.
Maximum path loss = transmit power – receiver sensitivity + gains – losses

Gains include any gains resulting from directional transmit and/or receive antennas. Antenna gains are usually expressed in dBi referenced to an isotropic antenna. Losses include any filter or cable attenuation or known environmental conditions. This relationship can also be stated as a link budget, which is the accounting of all gains and losses of a system to measure the signal strength at the receiver:
Received power = transmit power + gains – losses

Fade margin is used in calculation to provide for environmental conditions.
Maximum path loss = transmit power – receiver sensitivity + gains – losses – fade margin

B. Low Power Networks

Low-Power Network (**LPN**) or **Low Power Wide-Area Network** (**LPWAN**) is a type of wireless wide area telecommunication network designed to allow long range communications at a low bit rate among things with low-bandwidth connectivity (connected objects), such as sensors operated on a battery, focusing on range and power efficiency.
Low-power WAN technologies are designed for machine-to-machine (M2M) networking environments.

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With decreased power requirements, longer range and lower cost than a mobile network, LPNs are thought to enable a much wider range of M2M and Internet of Things (IoT) applications, which have been constrained by budgets and power issues.

LPN data transfer rates are very low, as is the power consumption of connected devices. LPN enables connectivity for networks of devices that require less bandwidth than what the standard home equipment provides. Furthermore, LPNs can operate at a lower cost, with greater power efficiency. The networks can also support more devices over a larger coverage area than consumer mobile technologies and have better bi-directionality.

The need for a technology such as LPN is much greater in industrial IoT, civic and commercial applications. In these environments, the huge numbers of connected devices can only be supported if communications are efficient and power costs low.

The various Low Power Network technologies are described as follows and they include:

- Bluetooth
- GSM
- Ingenu
- LoRaWAN
- LTE-MTC
- NB-IoT
- Sigfox
- Weightless
- Wi-Fi
- ZigBee
- 6LoWPAN

There are a number of competing standards and vendors in the LPN space, the most prominent of which include:

i. Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect up to seven devices, overcoming problems that older technologies had when attempting to connect to each other.

Bluetooth has range of 10 to 100 meters, 2.4GHz bandwidth and 3Mbps speed. It is secured and low cost. Bluetooth is password protected to ensure that system is secure and not misused by any intruders. It is a fast and cost-effective system.

For the implementation in IOT, it makes use of an Arduino Bluetooth board. An interactive Python program is used in the cell phone to provide the user interface. The I/O ports of Bluetooth board and relays are used for interfacing with the devices which are to be controlled. Python app on the phone is portable. A diagnostic system is present that can detect problems in the circuitry. A feedback system will report status of devices after every signal toggle.

Advantages of Bluetooth:

- Bluetooth devices can scan and detect other devices easily.
- It is possible to check if other devices are working properly or not.

Disadvantages of Bluetooth:

- Bluetooth takes a long time to discover and access devices in its vicinity.
- Does not provide energy conservation tips.
- Real time access cannot be achieved. Anywhere access to the devices cannot be achieved. Access is limited to within the Bluetooth range.

ii. GSM

GSMis used as a communication medium to help establish connection in places where there may not proper internet connectivity. It primarily uses SMS messages to communicateto main control system.GSM has the ability to control from all over the world.

Advantages of GSM:

- High availability, coverage and security.

Disadvantages of GSM:

- Cost incurred can be large.
- No assurance of delivery of message to the system. Thus, cannot be used as a real time system.

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iii. Ingenu (formerly On-Ramp Wireless)

Ingenu was founded in 2008 and originally focused on utilities and oil and gas applications; it has however expanded into other IoT applications including urban and agricultural environments. Ingenu has raised $119 million in venture funding to date and is the driving LPN solution behind a number of major smart meter and digital oilfield deployments. The firm's solution is proprietary in the sense that it is the sole developer and manufacturer of the hardware. Its major business model in the past was to sell hardware components to enterprises that built and controlled their own networks; recently however the firm has constructed several public networks, for which it sells radio modules and recurring data subscriptions – many customers for this model are machine-to-machine (M2M) solutions providers.

iv. LoRa Technology

LoRa is a technology developed by the chip manufacturer, Semtech. It offers fairly decent bandwidth compared to other LPN tech. Since it requires the use of Semtech's chip, it's not considered an open standard. LoRa has received traction in the European markets and there are a number of deployments today.

- The LoRa Alliance is a membership-based alliance dedicated to promoting and developing the LoRaWAN protocol. LoRa is an open alliance in the sense that any organization can purchase LoRa hardware and deploy its own networks without going through (and having to pay fees to) any centralized authority.
- Due to the modulation technique and built-in forward error correcting capability, the LoRa signal can transmit data with signal strengths well below the noise floor – LoRa proponents claim that LoRa is the only commercially available technology that can transmit so far below the noise floor.
- Another important consideration is that LoRa offers effective bidirectional functionality – so it is good for receiving messages from endpoints, but also for sending messages from base stations to endpoints (like for command and control applications).

v. LTE-M

LTE-M is part of Release 13 of the 3GPP standard, to lower power consumption, reduce device complexity/cost, and provide deeper coverage to reach challenging locations (e.g., deep inside buildings). It also boasts the highest security of LPN technologies.

vi. NB IoT

The requirements of NB IoT have just been finalized as of early 2016. This new narrow band radio technology provides an appropriate LTE category for low-bandwidth IoT devices. It leverages the existing infrastructure of LTE and GSM network providers to facilitate low bandwidth communications for IoT devices.

vii. SIGFOX

SIGFOX is suited best for the lowest bandwidth applications with extremely tight energy budgets.SIGFOX is that it is an entirely separate network for IoT devices. It's an open standard operating over the sub-GHz frequency bands (868 MHz in Europe and 900 MHz in USA) and any radio provider can use it.

- Sigfox sets up base station antennas on towers and often works with local mobile network operators (MNOs) to do so. It controls the backhaul communications infrastructure and backend cloud management platform, so any customer that wants to use Sigfox has to leverage its communications infrastructure and cloud platform – and of course pay the associated recurring fees. Radios and modules for endpoints are widely available from manufacturers like Texas Instruments, Atmel, and Telit.
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viii. Weightless standard

Weightless standard is developed and maintained by the Weightless Specialty Interest Group (SIG). There are several implementations of the Weightless standard (Weightless-W, -N, and -P) that leverage different underlying technologies and target different bandwidth applications. The company Nwave is one of the major proponents commercializing Weightless technology. A Weightless-N network will enable a mean data rate of 30kbits/s (higher peak) which exceeds the requirements of the majority of IoT use cases.

ix. Wi-Fi (Wireless Fidelity)

IEEE 802.11ah is a wireless networking protocol that is an amendment of the IEEE 802.11-2007 wireless networking standard. It uses sub-1 GHz license-exempt bands to provide extended range Wi-Fi networks, compared to

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conventional Wi-Fi networks operating in the 2.4 GHz and 5GHz bands. It also benefits from lower energy consumption, allowing the creation of large groups of stations or sensors that cooperate to share the signal, supporting the concept of the Internet of Things (IoT). The protocol is intended to be competitive with Bluetooth with its low power consumption, but with a wider coverage range.

Wi-Fi is a wireless technology that uses radio frequency to transmit days through air. It has initial speeds of 1Mbps to 2Mbps. It implements the concept of frequency-division multiplexing technology. Range of Wi-Fi technology is 40-300 feet.

x. ZigBee

ZigBeeis an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection.

- The technology defined by the ZigBee specification is intended to be simpler and less expensive than other networks, such as Bluetooth or Wi-Fi. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer.
- Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys.) ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device.

ZigBee Smart Energy relies on ZigBee IP, a network layer that routes standard IPv6 traffic over IEEE 802.15.4 using 6LoWPAN header compression.

Advantages of:

- Low power
- Robust
- Mesh networking
- Interoperability

Drawback: ZigBee is a low range communication medium. So remote access is hindered from faraway locations.

xi. 6LoWPAN

6LoWPAN is a group of internet standards created to tackle the problems of standard protocols that do not perform well in low-power wireless networks.

It implements a lightweight IPv6 stack adapted to low-power wireless devices especially well-suitedfor low power wireless mesh networks.

Advantages of 6LoWPAN:

- 6LoWPAN provides wireless internet connectivity to low power devices with limited processing capabilities.
- Interoperability and integration with current heterogeneous internet-aware devices is accomplished with 6LoWPAN to expand IoT.

Disadvantages of 6LoWPAN:

Existing mobility protocols or management protocols cannot be directly applied to 6LoWPAN devices. Since they are inefficient in terms of energy, communication and computation costs.

The Future Of LPN

One of the major risks to LPNs are LTE-M, LTE Cat-0 and NB-LTE, proposed cellular standards being pushed by various industry incumbents. Major operators like AT&T and Verizon could upgrade cellular software on their networks and deploy this kind of network with the flip of a switch. By reframing the GSM frequencies for voice in use today —and without needing any additional hardware—cellular companies can service narrowband applications.

Most likely, cellular companies will market LTE-M to large companies who use the cellular providers for voice field services. Because the cell providers are picking up $100 million for voice contracts, they have an opportunity to offer low-end data services for pennies on the dollar. If and when they decide to do so, they have an opportunity to steal some dramatic market share. This is almost analogous to what happened with 2G.

But this doesn't mean that companies in the LPN space are doomed—it just means they need to think ahead about

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new strategies. Ideally, they must try to provide more value than just transport of data. If LoRa Alliance members and customers of SIGFOX can come up with much targeted applications, they won't be displaced by LTE-M opportunities.

C. High Power Networks

People tend to look to newer wireless routers in hopes of wiping out the dead spots that exist in most homes. The nice thing about higher power is that it is it can easily and reliably be measured and verified. In fact, maximum power measurement is required for FCC certification, to ensure that products don't exceed mandated limits.

Unfortunately, simply swapping out our current router for a higher power usually doesn't help increase our wireless coverage. The 802.11 standards that all Wi-Fi networks are built on use a "positive acknowledgement" protocol. That means each data packet (or frame) that is sent must be acknowledged by the receiver via a reply back to the sender. If no acknowledgement is received, the sender will try again and again until a timeout is reached and the sender gives up and drops the connection.

So when we increase the power on a wireless router or access point, all this does is make it "shout louder". Sure, a wireless notebook in a dead zone may now be able to "hear" the router, where it couldn't before. But unless the client can shout just as loudly back, the client won't be able to communicate with the AP and the connection will be dropped or won't be made at all.

There are two solutions to this problem: increase antenna gain; or also boost the signal on the client end. Boosting transmit power on both ends of the connection can get expensive and impractical if we have a lot of clients. it is not recommended as a way to improve coverage. But it's certainly the way to go if we are to link two buildings together via wireless.

Increasing antenna gain gives us more flexibility because we can do it on the router/AP or client or both. a higher gain antenna can succeed where higher power doesn't because it's amplifies both the transmitted and received signals.

So we can install higher gain antennas on our router/AP, leave the clients as-is and see real results. of if we've got one computer with an iffy (or no) connection, swapping in an adapter that has more power, higher gain antennas or both can get better done.

But we need to move up to an antenna with at least 6dBi gain to see a performance difference. And we'll need to upgrade all the antennas on the AP/router to see an effect.

Although harder to find, we can still get routers and access points with external connectorized antennas that we can swap for higher power ones. Check the router and wireless finders and use the antenna upgradeable filter to find them.

III. CONCLUSION

It is important to understand the very real applications for low power and high power networks. The numbers are huge—there are trillions of connected devices which is growing at a large scale. This technology isn't going to be displaced anytime soon, and it is quite disruptive in many ways.

These networks capture a large portion of high-end data contracts and will be able to cater to billions of medium to low-end contracts. These opportunities could have a huge impact on our world—from helping to feed the global population, to reducing the amount of water consumed, to cutting back on energy consumption, and so much more. These networks empower very real applications, because they make more efficient decisions about how to utilize resources.

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