A Proposal for Applying Adaptive Wireless Communication System for Smart Factory

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ABSTRACT

Activities to deploying devices that connect Internet, said Internet of Things in the industrial domain are accelerating to improve efficiency, prevent down time led by organizations such as Industry 4.0 and Industrial Internet Consortium. Moreover a trend in industrial domain that manufactures have to provide various and small amount of products let manufactures reorganize their manufacturing facilities frequently. In often the case, the most costly portion of the reorganization is re-cabling cost. Basing on this background, wireless communications are highly desired especially devices that can operate without power line. In this study, we propose a wireless communication system that configure properties of the system such as carrier wave frequency, bandwidth, modulation autonomously depending on application requirements and circumstance of radio wave propagation.

1. INTRODUCTION

As for getting profits by running factory, manufactures have to take account of cost for reorganization plant floor based on the trend that manufactures are required to provide small amount of various products. Reorganization plant floor is costly, especially the re-cabling cost occupies a big portion of the total cost. Wireless communication systems are highly desired to reduce the cost.

However, applying only existing commodity wireless communication system such as Wi-Fi or Zigbee, never satisfies manufacture's requirements such as communication rates (includes cases that the rate is over killed for some application), stability, environmental issues (e.g. heat, vibration, radio propagation model of respective frequency bands), battery life, and durability.

In this paper, we propose a wireless communication system which operates with variable carrier frequency, bandwidth, emitting power and modulation methods autonomously depending on the analysis of the respective requirements of applications on the plant floor. The system enables to utilize limited wireless resources very efficiently. In chapter 2, we discuss requirements of wireless communication in the plant floor. We glance at today's digital modulation technology in chapter 3, describe how the proposing wireless system works in chapter 4. In chapter 5 we explain issues to embody the proposing system, and conclude in chapter 6.

2. ENVIRONMENT FOR OPERATING WIRELESS SYSTEMS ON PLANT FLOOR

On the plant floor, devices such as censors, actuators, conveyers, and Programmable Logic Controllers are connected to different types of wired network. The types of the wired network are chosen by required bandwidth and latency. We discuss requirements to replace the wired network with wireless communication systems.

2.1. Noises on the plant floor

To deploying wireless communication systems, the noise environment of plant floor is firstly coming to mind. Basically, all devices on the plant floor are EMC certified. Surge noises contains 1GHz wave in their spectrum. However the power level of the 1GHz is low enough to ignore.

2.2. Multipath

If requirement of bandwidth is high, carrier wave frequency tends to high as well. Since a lot of equipment's are made from metal multipath is an issue to be considered.

2.3. Fading

As receiver gets larger number of multipath waves, radio signal strength gets weaker by the fading.

2.4. Radio Propagation Model

On the typical plant floor, there are many objects made from metal such as power lines connected vertically from inner roof, types of machines, conveyers.

The radio propagation model is more complicated as the carrier frequency is getting higher. For example it is said that there are 30 or more of multipath waves at 2.4 GHz, the ISM band. The radio propagation model should be the

Rayleigh distribution where the Line of Sight wave is not contained between sender and receiver.

2.5. Regulation

Most of plant floors deploy some degree of shield to avoid disturbing their neighbors from to listing AM radio broadcast that occupies frequency range of 500 KHz to 1700 KHz. A new regulation should be allocated if it needs.

In the case of Japanese FCC, if the shield lessens 40dB of signal strength, the plant floor is admitted as radio dark room.

3. VARIATION OF MODULATION METHODS.

We provide certain modulation methods to satisfy the requirements. Following compare the characteristics of respective modulation methods.

Table 1. Characteristics of modulation methods

Method	Characteristics
ASK	Mapping 2 state of baseband signal to certain level of 2 signal strength. Simplest but uncertain bandwidth of carrier wave
FSK	Like the ASK, mapping to 2 state of frequency, bandwidth between 2 frequency should be minimum (MSK)
PSK	Mapping baseband signal to phase sift of carrier wave. Sifting state is limited to 8 mostly
QAM	Mapping baseband signal to phase sift and amplitude. Up to 1024 symbols are mapped per wave
OFDM	Utilizes multiple carrier waves in continuous frequency. By being respective QAM phase orthogonal, packs the bandwidth effectively
MIMO	Utilizes multiple OFDM bands

4. AUTONOMOUS WIRELESS COMMUNICATION CONFIGURATION SYSTEM

We propose the autonomous wireless communication configuration system which is to enable using limited wireless efficiently while satisfying communication requirements of applications. We defined a strategy to achieve the purpose as listed below.

1. Seek the lowest frequency with the narrowest bandwidth modulation for required by an application
2. If the seeking frequency exceeds the highest frequency that physically reachable, try to occupy wider frequency band by applying wider modulation method

4.1. Architecture of wireless communication device

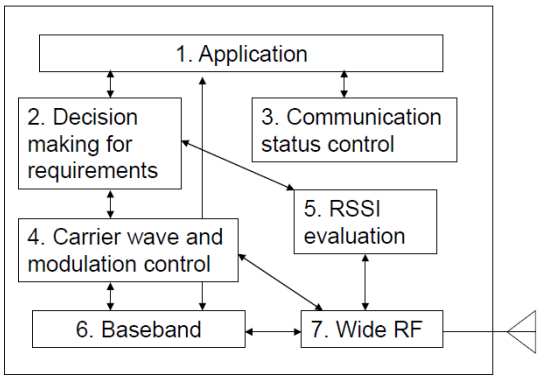

Figure 1. Architecture of wireless communication device

1. The application is a program which uses wireless communications. The application gives its communication requirements to the decision making unit
2. Basing on the RSSI evaluation, Decision making unit chooses the best wireless configuration depending on the given requirements from the application
3. The communication status control keeps wireless status information of the wireless communication such as operating carrier frequency and adopted modulation method
4. The carrier wave and modulation control configures data rate for the baseband, and the carrier frequency and modulation method to the wideband RF
5. The RSSI (Received Signal Strength Indication) evaluation tells it self and the other wireless communication device in the network allocated in ad hoc fashion
6. The baseband converter
7. Wide band RF which covers 10 MHz to a few GHz with types of modulation methods which are discussed above

4.2. Algorism for configure autonomous wireless network

A user who uses this wireless systems places the devices on certain positions. Those devices may connect to the wired networks of plant floor. However this issue is out of scope of this paper.

All the device's initial frequency is set to the same. One of the devices assigned as the master, and the others are assigned as the slave.

The master device broadcasts QPSK modulated probe message to the slaves and the slaves send the respective RSSI to the master.

If the carrier frequency is not high enough, all the devices increments the carrier frequency by say 10 KHz.

If the carrier frequency raised high enough for satisfying the requirement, all the devices set the current configuration as the operating carrier frequency and modulation.

Since in automation systems, payload of messages handled on the plant floor is not large, most of the wireless network communication systems would be allocated by the simple protocol as described.

4.3. In the case the high data rates are required

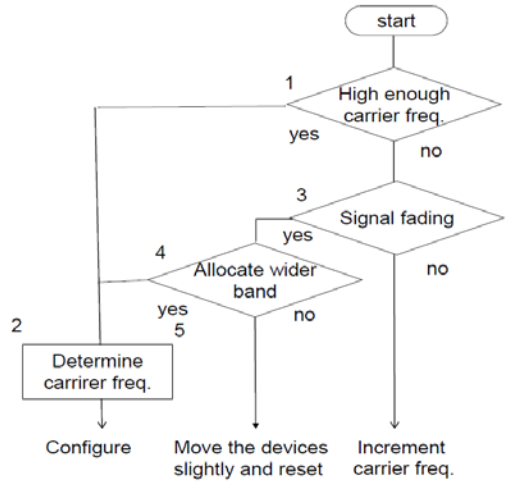

Figure 2. Algorism for allocating wider band

1. The carrier frequency is determined in simple way as described
2. And configured as explained
3. If the carrier frequency exceeded the limit
4. Allocate broader frequency band below the limit frequency
5. Success to allocate the frequency band, configure with proper modulation method

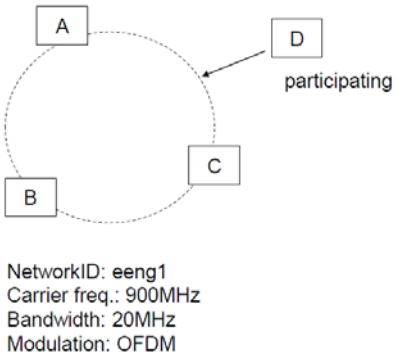

Figure 3. An example of the wireless communication network

Figure 3 depicts an example of the wireless communication network additional device can participate the network by beacon message from the master device which contains profile information of the network, and the device in the network can exit from the network.

5. ISSUES AND POSSIBLE SOLUTIONS

The wireless communication system in this proposal seems costly since the device should prepare multiple modulation methods. However, as shown in a combo-chip of wireless LAN and Bluetooth which like Intel provides, once implemented as an IC, even the cost of multi modulation IC is not so high comparing simple modulation IC.

On the plant floor, there are many of moving metal objects such as robots, works of metal on conveyers. This proposal provides a robust wireless communication system as well.

6. CONCLUSION

We discussed wireless communication system for plant floors where are occupied with many of metallic objects. We will brush up the system for robustness and will lessen the cost of the system

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