Efficient RFID Modulation Scheme for Better Ubiquitous Network Performance

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Abstract - This paper presents an ongoing investigation into the effect of modulation schemes on Radio Frequency Identification performance and forecast the implication for a ubiquitous network such as the future Internet of Things. The paper plans to employ the use of two popular metrics – Bit Error Ratio and Signal-to-Noise Ratio to evaluate the success rate of the digital data transmission in RFID. The best modulation technique to achieve the best data transmission rates between readers and tags at an optimum power level would be established. It is hoped that the research results when completed would enhance the performance index of the future ubiquitous network.

Keywords - Internet of Things; Modulation Scheme; Radio Frequency Identification; Reader; Tag; Ubiquitous Network

I. INTRODUCTION

Advances in microchip technology are helping to extend the application of Radio Frequency Identification (RFID) of its applications include supply chain management, airline ticketing/baggage handling object tracking, anti-counterfeiting, healthcare, sensor applications (data acquisition), and security/access control [1].

With the increasing relevance of RFID and other technologies, such as Wireless Sensor Networks (WSN), the materialization of the 1998 forecast of Internet of Things (IoT) by Kevin Ashton is already evident [2]. IoT is stepping boldly as the next evolutionary technology in transforming the internet into a fully integrated future network. As the technologies converge and transit to ubiquitous networks, the need for data-on-demand using sophisticated schemes increase significantly [3]. IoT aims at increasing the ubiquity of the Internet by integrating devices everywhere and anytime for interaction through embedded systems. This would be yet another disruptive demand on wireless networks. Device interface would move from human-centric to machine type [4][5]. By integrating RFID systems with IoT, a pervasive system can be created that will provide richer and faster information about objects, as well as their locations [6]

Increasing the primary device for internet connection is steadily becoming wireless [7]. At the moment, there are about 7 billion devices with wireless connectivity in use. This number is expected to be surpassed by the time IoT fully comes on stream as subscribers base is projected to grow between 10 and 100 fold due to many new applications beyond personal communications [8].

With the role RFID is expected to play in IoT, this paper will discuss RFID technology and propose an improved modulation scheme. This is expected to better the data transmission performance of RFID and hence improve the overall data rate of the future Internet of Things architecture in wireless networks. In this research,
implementation is based on the IEEE 802.11p wireless standard.

The rest of the paper is organized as follows: Section 2 is review of related works, while Section 3 deals with RFID tags, Section 4 are READER, while Section 5 antenna and host computer, Section 6 performance measurement and finally Section 7 concludes the paper.

II. REVIEW OF RELATED WORKS

Many accounts suggest that the closest origin of RFID as it is known today is the radio-based identification system used during World War II. Then, Radio Frequency signals were innovatively used to identify friend or foe aircrafts. This helped to forestall accidental attack on allied fighters and recognition of enemy aircrafts. The system worked by sending coded identification signals to an advancing jetfighter. A correct response indicated a friend, else a foe. The success of this system led to the birth of what is today referred to as the Radio Frequency Identification [9].

The aim of RFID is to track support objects. There have been increased discussions to integrate Wireless Sensor Networks with the RFID systems. WSN has considerable advantages in collecting and analyzing environmental information better than RFID. Therefore, by integrating RFID systems with WSNs, an object tracking and management system that will offer vital information about the environments of objects would have been realized [6]. Meanwhile, the Internet of Things is offering a promising prospect to create a potent system and applications by leveraging the expanding ubiquity of radio frequency identification, wireless and sensor devices [17].

Radio frequency identification (RFID) has gradually become a significant catalyst for enhancing the velocity of information flow by surmounting the limitations of traditional manual and other data collection techniques such as bar codes. The technology has attracted considerable interest as it has established the potential to enhance efficiencies across business processes by creating a technique to attach unique identification to objects and allow the objects to move with the information. It is capable of focusing on real-time optimization by enabling accurate, timely visibility of the various processes of its activities and make strategic intelligent decisions [18].

Radio Frequency Identification is based on the detection of electromagnetic Radio Frequency signals using wireless sensor technology [10]. The frequencies deployed in RFID systems are examined in table I. RFID aims at automatically identifying unique items using radio waves by detecting tags attached to such items. An RFID tag contains information that can be read by an RFID scanner or reader. This information could be in the form of a single binary bit, or as large as an array of bits representing such things as an identity code [11]. In very broad terms, RFID comprise of three basic elements; Tag, Reader, and a host Computer

III. RFID TAG

An RFID tag, which is also known as transponder consist of an electronic circuit or silicon chip that is embedded with an integrated antenna and non-volatile memory. A tag generally comes alive when within range of an electromagnetic Radio Frequency (RF) wave of an RFID scanner called a Reader. Some modern RFID tags now integrate with other technologies like Wireless Sensor Networks (WSN) and General Packet Radio Service (GPRS) for tracking purposes and to enhance connectivity. Tags can be classified into three main types: Passive, Active and Semi-passive. Fig. 1 shows a passive RFID tag.

A. Passive Tags

These do not have independent power source. They obtain power from the electromagnetic field generated by the RFID Reader and tend to have longer shelf life. As a result, passive tags can only transmit over shorter distances with comparatively low frequencies, ranging 125 kHz – 134.2 kHz. Its memory capacity is 256 bytes.

B. Active Tags

Active tags have independent source of power such as a battery with a wider frequency range. They may run at frequencies ranging up to 915 MHz and 5.8 GHz, which can be read from a distance of 100 feet or more. Such tags usually have shorter shelf live. Active tags can have memory capacity of up to 3 Megabytes.
C. Semi-Passive

Between the active and the passive tags are the semi-passive tags. These tags have a battery, like active tags, but still use the reader’s power to transmit a message back to the RFID reader using a technique known as backscatter, which is common to passive tags. They may have frequency in the region of 13.56 MHz – 860MHz.

IV. READER

An RFID Reader is essentially an electronic device sometimes called interrogator or transceiver. It transmits and receives radio waves to and from an RFID tag. The Reader emits a pulse of radio energy to which the tag respond by basically sending its serial number [9]. The reader mainly interrogates the tag for stored information but sometimes a reader can be used to encode an RFID tag. Some of the coding schemes will be discussed shortly. But depending on the type of tag, a reader’s communication may be just a ping or a more complex protocol to be read without line-of-sight. Sometimes a reader may have to perform an anti-collision protocol to avoid communication conflicts. Such protocols allow readers to swiftly interact with a multitude of tags. RFID readers can come in fixed or mobile format and can also be a read only or read/write device.

A. Mobile Reader

Mobile or handheld RFID readers are portable interrogators that can be moved about. A small number of mobile readers can cover a large area without the burden of cables and wires. Mobile RFID readers are controlled by the user and reads when the trigger is activated towards zone(s) where the suspected tag is positioned.

B. Fixed Reader

Fixed readers are stationed to interrogate tags that come within its field. These are ideal for large scale deployments such as public buildings, entry and exit points, and warehouse etc. It is installed permanently in a defined position that supports constant listening as to detect RFID tags. Such readers require dedicated source of power and link to the host computer or connected network.

V. ANTENNA AND HOST COMPUTER

The antenna is primarily the device for transmitting or receiving electromagnetic signals between a RFID tag and reader. Table II shows the various frequency ranges and the corresponding antenna transmission dimensions. The host computer might be a stand alone or in a network. The function of the computer is to store and evaluate received data and connect the reader to relevant applications. What the computer does with a received data would depend on the application in use. In an access control, it will check whether the data transmitted is present on its database that permits access. If that is the case it grants access, else it does not.

A. Reader and Tag Communication

Majority of tags currently in use are passive. The use of batteries makes the cost, size, and life-span of active tags unattractive for commercial purposes. Basically there exist two different design strategies for transferring power from reader to tag in an RFID system. They are the magnetic induction and electromagnetic (EM) wave capture. Both design approach utilizes the EM properties associated with radio frequency antenna - the near-field and far-field. Depending on the type of tag, as much as between 10µW and 1mW of power is usually enough when transferred to sustain RFID operation [16]. Fig. 2 shows a reader in communication with a tag.

A passive tag derives energy when it enters the electromagnetic field which a reader emits through inductive coupling or far field energy. The passive tag without an independent source of power depends on the reader to receive signal within a narrow unlicensed frequency band which may be denoted as $f$. Inductive coupling induces a current in its coupling element (normally a capacitor and a coiled antenna) by utilizing the magnetic field produce by the communication signal. Hence, inductive coupling is only able to work in the near-field of the communication signal. For a given
frequency $f$, the near field stretches up to $1/(2\pi f)$ meters from the signal source. A tag at a distance $d$ from the reader, the operating voltage attained is directly proportional to the flux density at the given distance. The magnetic field emitted by the reader antenna decreases in power proportional to $1/d^3$ in the near field [14].

The reverse signalling from the tag to the reader in passive RFID systems is not achieved by active transmission. Passive tags do not actively transmit a signal, therefore, in the near field; tag to reader interaction is accomplished through load modulation. Load modulation is attained by modulating the impedance of the tag as seen by the reader.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Frequency (LF)</td>
<td>125 kHz – 134.2 kHz; This is low frequency (LF). It is able to detect tags within range of less than 0.5m. Usual data transfer rate is less than 1 kbit per/sec. The electromagnetic waves are able to penetrate water but not metal. LF can be used for identification of animals.</td>
</tr>
<tr>
<td>High Frequencies (HF)</td>
<td>13.56 MHz; The distance range for HF could be up to 1.5m, while the data transfer rate is roughly 25 kbit/sec. HF electromagnetic waves can penetrate water but not metal. Mostly used for access control and security</td>
</tr>
<tr>
<td>Ultra-High Frequencies (UHF)</td>
<td>433 MHz - 960 MHz; UHF can cover distance of up to 100m and has data transfer rate of 100 kbits per/sec. UHF cannot penetrate water or metals. Mostly used in logistics.</td>
</tr>
<tr>
<td>Super High Frequencies (SHF)</td>
<td>2.45 GHz; SHF detects a tag more than a distance of 100m, while its data transfer rate is 100 kbits per/sec. It is considered as microwave frequency and cannot penetrate water or metal. SHF is mostly used for vehicle toll. The 5.9 GHz band spectrum is also been allocated.</td>
</tr>
</tbody>
</table>

In the far field, tag to reader communication is realized through backscatter. Backscatter is attained by modulating the radar cross-section of the tag antenna [14].

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Antenna Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.56 MHz low reading range (30cm)</td>
<td>20cm x 20cm</td>
</tr>
<tr>
<td>13.56 MHz low reading range (2m)</td>
<td>75cm x 90cm</td>
</tr>
<tr>
<td>900MHz</td>
<td>7.5cm - 15cm</td>
</tr>
<tr>
<td>2.4GHz</td>
<td>3cm - 6cm</td>
</tr>
</tbody>
</table>

VI. LINE CODING, MODULATION SCHEMES AND PROTOCOLS

A. Coding Scheme for RFID

The data, sent between readers and tags consist of ones and zeros. To ensure a safe and reliable communication between tag and reader, data must be encoded before transmission. This requires the modulation of the transmission signal. The combination of coding and modulation schemes determines the bandwidth, integrity, and tag power consumption.

Modulation is simply the variation of the amplitude, frequency, or phase of the carrier, or a combination thereof, in accordance with the digital information to be transmitted [15].

There are a number of organizations working to develop acceptable international standards for RFID technologies, these organizations include International Organization for Standardization (ISO), the International Electro-technical Commission (IEC), and Electronic Product Code Global (EPCglobal) [11]. The protocol utilized in this research is the EM4100 RFID specification. In order to determine a suitable coding scheme for RFID, 3 important factors must be considered:

- The code should be able to provide power to the tag
- The code must have limited bandwidth and
- Be able to detect collisions

Depending on the bandwidth available, most RFID systems use Pulse Pause Modulation (PPM) or Pulse Width Modulation to communicate from reader to tag and Manchester or NRZ to communicate from tag to reader. The simplest code is Pulse Pause Modulation (PPM) in which the length between pulses is used to convey the bit. PPM codes provide low bit rates but occupy only a small bandwidth and are very easy to implement. In addition, these encodings can be adapted easily to ensure uninterrupted power supply since the signal does not change for long period of time.

EM4100 compatible RFID interrogators carry 64 bits of Read Only memory. This 64 bits memory is made up of a header and 3 sets of data. Following the header is data containing manufacturer’s code. The third part represents the product code such as the Stock-Keeping Unit (SKU), finally the fourth part represents the code unique to the tagged item. The format of the data is as shown.
TABLE III. DATA FORMAT

<table>
<thead>
<tr>
<th>9 Bits Header</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
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<tbody>
<tr>
<td>8 bits version number or ID</td>
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<tr>
<td>D00</td>
<td>D01</td>
<td>D02</td>
<td>D03</td>
<td>P0</td>
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<td>D04</td>
<td>D05</td>
<td>D06</td>
<td>D07</td>
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<td>D08</td>
<td>D09</td>
<td>D10</td>
<td>D11</td>
<td>P2</td>
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<td>D12</td>
<td>D13</td>
<td>D14</td>
<td>D15</td>
<td>P3</td>
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<td>D16</td>
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<td>D20</td>
<td>D21</td>
<td>D22</td>
<td>D23</td>
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<td>D24</td>
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<td>D28</td>
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<td>D36</td>
<td>D37</td>
<td>D38</td>
<td>D39</td>
<td>P9</td>
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<tr>
<td>PC0</td>
<td>PC1</td>
<td>PC2</td>
<td>PC3</td>
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TABLE IV. ENCODED DATA FOR RFID TAG

<table>
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<tr>
<th>9 Bits Header</th>
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<tbody>
<tr>
<td>(10 rows of data - the card serial number) The first 4 bits are the data; the last is the even parity bit.</td>
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As shown in table III, it starts with a 9-bit header with a group of 4 bits data which is followed by an even parity bit. On the bottom it has 4 column Parity bits and finally a stop bit (0). The tag will transmit this string of data as long as it receives power (within the range of an electromagnetic field provided by the reader).

Parity bits = [Header + ID + Data + Parity] (1)

For instance using the above scheme, a tag that has the encoded data $06 \text{ (version identify no.)}$ and $001259E3 \text{ as a data string}$ will output as follows

```
111111111 00000 01100 00000 00000 00011 00101
0       6       0       0       1       2
01010 10010 11101 00110 01000 5 9 E 3
```

B. Data Modulation

Normally the data coding scheme will define how the data is represented. But how the bits stream is sent between tag and reader is decided by the modulation scheme. The known classes of digital modulation are Frequency Shift Keying (FSK), Amplitude Shift Keying (ASK) and Phase Shift Keying (PSK). Usually, the modulation type will be determined by power consumption, bandwidth and reliability requirements. At a frequency of 13.56MHz ASK is commonly used. Here this paper intends to utilize the 2 common modulation schemes - ASK and PSK encoding.

Note that the Tag and Interrogator employ the individual cycles of the Radio Frequency field to synchronize the data transmission between the Tag and Reader. Though the RFID clock frequencies changes depending on the application, the frequency synchronizing clock automatically becomes the frequency of the Radio Frequency field. Fig. 3 shows three popular examples of modulation schemes.

VII. PERFORMANCE MEASUREMENT

This section deals with analysis of some parameters in the proposed technique.

A. BER and SNR calculations

An understanding of Bit rate and Symbol rate is vital in order to evaluate the performance of different modulation techniques. The communication channel signal bandwidth depends on symbol rate, also called the baud rate. Bit rate is the number of bits that are transmitted per unit of time. Symbol rate is the amount of symbol changes made to the transmission medium per second using a digital modulated signal measured in baud or symbol per second.

Symbol rate = Bit rate/ Number of bits transmitted per second (2)

Bit Error rate (BER) refers to the ratio of the number of bits incorrectly received against the total number of bits sent during a specific time interval.

Using the Additive White Gaussian Noise (AWGN) this can be expressed as

$$\text{BER}_{\text{AWGN}} = \frac{1}{2} \text{erfc}(\sqrt{\frac{b}{N_0}})$$ (3)

Calculating BER for one-path Raleigh fading channel

$$\text{BER}_{\text{FADING}} = \frac{1}{2} \frac{1}{\sqrt{2\pi \lambda_b}} e^{-\frac{1}{2\lambda_b}}$$ (4)

Where $\lambda_b/N_0$ is the ratio between energy per bit ($\lambda_b$) and noise density ($N_0$)

$$\text{SNR} = 10\log_{10} (\text{signal power}/\text{Noise power}) \text{ dB}$$ (5)

The probability of a symbol error for the M-ary QAM system in the presence of AWGN as a function of $\lambda_b/N_0$ is given as
P_b = 2(1 - \frac{1}{\sqrt{2\pi}} \exp(-\frac{K}{2}) \{ E_b/N_0\})..........................(6)

Where K = \log 2M and \frac{E_b}{N_0} denotes ratio of bit energy \( E_b \) to noise power spectral density \( N_0 \).

It is an expression of SNR normalized by bandwidth \( B \), and bit rate \( R_b \) denoted by \( \frac{E_b}{N_0} = S/N(B/R_b) \) .....................................................(7)

For RFID system, bit error and symbol error are identical as each symbol error corresponds to a single bit error. When Gray-coding is used in mapping, Bit error probability \( P_b \) will be given by

\[ P_b \propto \frac{2^K}{K} \]

where \( K = \log 2M \), \( P_b = \text{Bit error probability} \) [20]

\[ \text{Ps} = 2(1 - \frac{1}{\sqrt{2\pi}} \exp(-\frac{K}{2}) \{ \frac{E_b}{N_0}\}) \]

D. Cost

Many organizations are reluctant to embark on the deployment of RFID technology due to the cost and time of tagging objects. Some libraries have had to disrupt their operations by closing significant sections of their services in order to tag books and other library items.

E. Standardization, Integration and Convergence

Implementation of compatible standards for RFID systems has remained a difficult subject. Numerous RFID standards are in existence and their applications are under debate within the RFID research and development community. Some of the standards cover the following areas.

- Air interface - issues of wireless interactions between transceivers and transponders
- Identification - issues relating to encoding data to the radio frequency tag
- System protocols - defining the middleware of an RFID system
- Application support services - issues relating to how the RFID system should be implemented
- Health & safety regulations and
- Terminologies

The International Standards Organization (ISO) has developed three standards for RFID: ISO 14443 (for contactless systems), ISO 15693 (for vicinity systems, such as ID badges), and ISO 18000 (to specify the air interface for a variety of RFID applications). Also EPCglobal – a not-for-profit organization has developed RFID standard for air interfaces which has so far been widely received. Various other organizations have developed or are in line to develop similar standards, thereby making common standards yet a challenge [19].

VIII. CONCLUSION AND FUTURE WORKS

This paper has analyzed the fundamentals of the RFID system. It has identified the modulation technique as a strategy for boosting digital data transmission for RFID technology. It plans to select the modulation type by power consumption, bandwidth and reliability requirements, and then determine the appropriate technique with a balance of power using a selection of equations involving SNR and BER. With an enhanced RFID transmission rate, an improved performance for the future Internet of Things is expected as a result.
A. Future works

Future work would include a comprehensive performance evaluation of RFID modulation schemes using BER and SNR. Such comparison would take into account coding scheme complexity, cost, privacy and all other challenges facing high adoption of RFID technology.

REFERENCES


