

# Power Consumption Measurement and Clock Synchronization on Low-Power Wireless Sensor Networks

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**Abstract**— Smart Grid becomes a hot topic in recent years in carbon reduction as well as environmental protection. However, in order to facilitate efficient use of energy to solve energy shortage problem, it must be supported by a robust two-way communication network, and this further stimulates related researches on wireless sensor networks. This paper studies two major issues in wireless sensor networks. The first is the power consumption of wireless sensors. We compared ZigBee with Low-Power WiFi on their power consumption. In our experiments, in order to precisely measure the low power consumption of ZigBee and Low-Power WiFi, a digital oscilloscope was utilized to help us to compare their power consumption in start-up and stand-by statuses.

The second issue is clock synchronization. Because time accuracy is a big issue for disaster prevention, the clock of every sensor node must be synchronized. In this paper, we established a clock synchronizing system which adopts Network Time Protocol (NTP) with Low-Power WiFi devices.

**Keywords**— Low-Power WiFi, Measurement, NTP, Smart Grid, Time Synchronizing, Wireless Sensor Networks, ZigBee

## I. INTRODUCTION

In recent years the importance of environmental protection received global recognition, and in order to achieve carbon reduction, many countries proposed Smart Grid [1] as a means to improve the efficiency of energy management. However, to manage critical services on Smart Grid, it must be supported by an efficient and robust two-way communication network.

Wireless Sensor Networks (WSNs) [2] plays an important role in Smart Grid. In order to better understand energy consumption status, sensors are deployed to the premises of end users and periodically report the energy consumption status to energy managers and consumers. With the information collected from these sensors, Smart Grid is able to coordinate related devices to achieve more efficient use of energy.

ZigBee is a famous protocol in wireless sensor networks. Compared with WiFi, ZigBee is an ideal choice for low-power communication technology [3]. Later, another

type of wireless sensors were announced to be equipped with "Low-Power WiFi" [4], which claims to achieve the same level of low-power consumption as ZigBee. Because the Low-Power WiFi sensor devices can natively support Internet Protocol (IP), which is mature and widely available, many existing applications can be easily integrated with these Low-Power WiFi devices. This makes it a promising communication choice in wireless sensor networks, too.

In this paper, the power consumption of Low-Power WiFi and ZigBee sensors was measured and compared to analyze their efficiency in Smart Grid applications.

In addition to energy saving, disaster prevention is also an important application of wireless sensor networks. With widely deployed sensors, we can monitor the change of environment, such as rainfalls and landslides. However, in disaster prevention, we need environmental information reported with accurate timestamps, so clock synchronization becomes an important issue, too. In this paper, we also demonstrated the system architecture of a wireless sensor network whose clocks are synchronized with Network Time Protocol (NTP). With further accuracy improvement, it can be applied to disaster prevention systems.

## II. WIRELESS SENSOR NETWORKS

With the technological advancements of communication, and battery charge, small sensors are now capable of sensing and communicating wirelessly. ZigBee is a popular protocol of wireless sensor networks. Developed for personal area networks (PANs), the hardware standard is specified by IEEE 802.15.4 while the software is standardized by ZigBee Alliance. It is a simple communication protocol with good compatibility and market acceptance. ZigBee is designed to transmit at low transmission rate (250 kbps), short communication distance (50m to 100m), and low power consumption.

Figure 1 shows that wireless sensor networks (WSNs) can be used for home appliances automation, environmental safety, healthcare, Smart Grid, and so on.

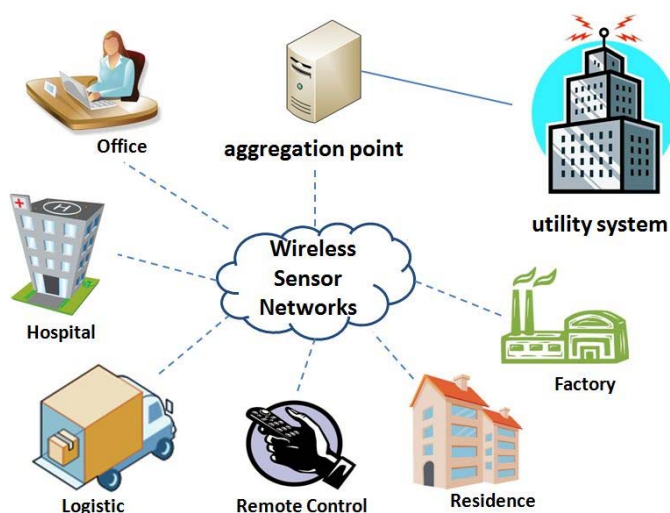


Figure 1. Applications of Wireless Sensor Networks.

In 2009, a new type of wireless sensor devices — Low-Power WiFi, was also proposed. It conforms to the IEEE 802.11 (WiFi) standard which has been extensively used in wireless networks all over the globe. As mentioned in [4], Low-Power WiFi provides the same functionality as WiFi. Because it can be managed and configured remotely using Simple Network management Protocol (SNMP), and it supports WiFi encryption, authentication and related Wi-Fi Protected Access (WPA), it can be easily integrated with existing services running on the Internet. Therefore, it is proposed that WSNs can be built with Low-Power WiFi, as shown in Figure 2. This allows it to reduce the power consumption of sensors, while keep easy integration with the existing IP infrastructure.

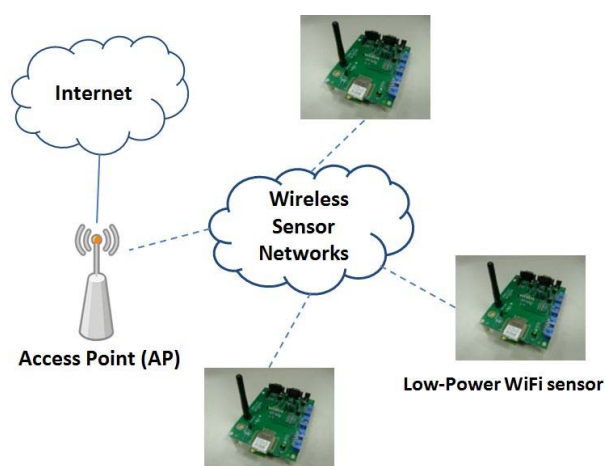


Figure 2. Low-Power WiFi system architecture.

### III. POWER CONSUMPTION MEASUREMENT

Although ZigBee and Low-Power WiFi are both WSNs which claim to consume low power, it is worthy of comparing their actual power consumption, especially at different statuses, such as start-up, beaconing and stand-by.

Figure 3 shows the connection diagram when we measure the power consumption with a digital oscilloscope. All measurement information of digital oscilloscope with a power consumption measurement device will be sent a PC through a serial port by universal asynchronous receiver/transmitter (UART). The PC can control voltage and current a programmable DC power supply, also through a serial port by UART. It was useful to stabilize voltage and current with a measurement device, so that it can be easy to observe the oscillogram.

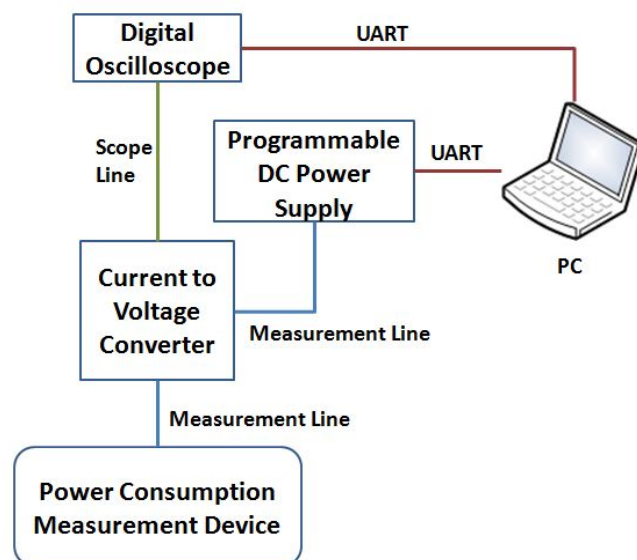


Figure 3. Digital oscilloscope connection diagram.

#### A. Low-Power WiFi Power Consumption Measurement

In this Low-Power WiFi experiment, we observed an important relationship with low power consumption of beaconing status and WiFi access point (AP) signaling strength.

Figure 4 and Figure 5 show the electric currents corresponding to different AP signaling strength. When the AP signal strength is weak (as in Figure 4), it can be seen clearly that an end-device consumes more power (29mA vs. 65 mA).

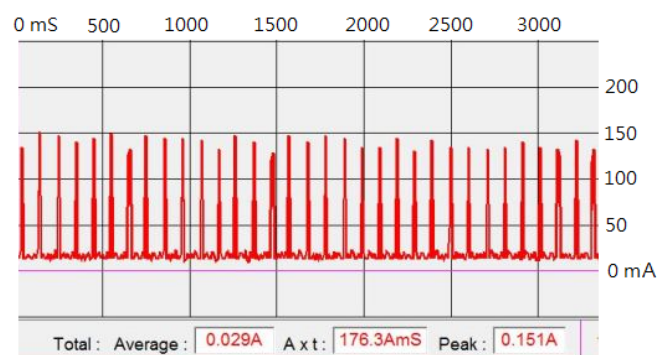
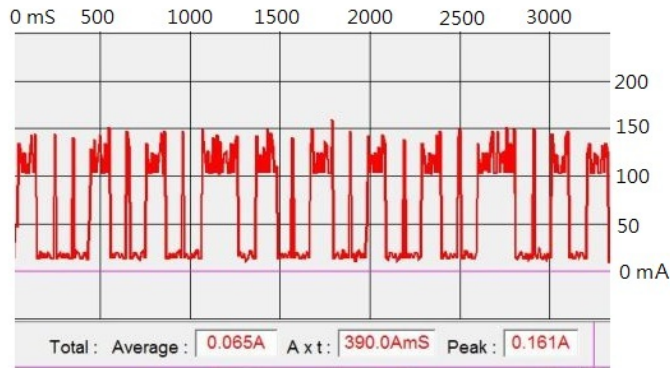


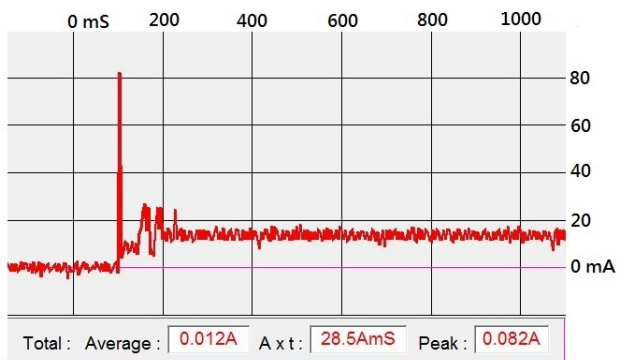
Figure 4. The electric current of beaconing status when the WiFi

signaling strength is -32 dBm.



**Figure 5.** The electric current of beaconing status when the WiFi signaling strength is -79 dBm.

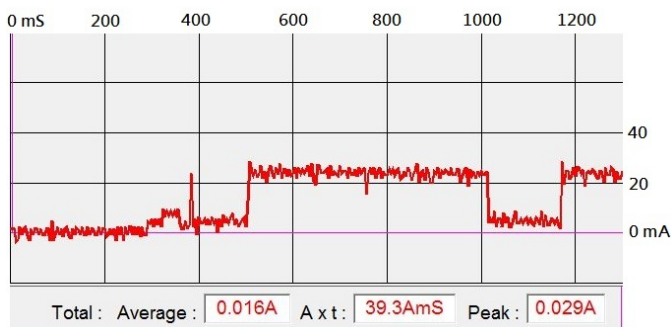
Figure 6 shows the energy consumption at start-up.



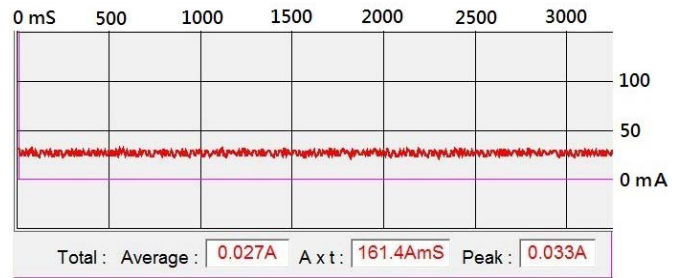
**Figure 6.** The start- up status of Low-Power WiFi.

### B. ZigBee Power Consumption Measurement

Similar measurement data about ZigBee can be found in [1]. Figure 7 and Figure 8 show our measurement of power consumption of ZigBee devices at start-up and stand-by statuses, respectively.



**Figure 7.** The start- up status of ZigBee.



**Figure 8.** The stand-by status of ZigBee.

**TABLE 1.** Average power consumption statistics

| Power State        | ZigBee   | Low-Power WiFi |          |
|--------------------|----------|----------------|----------|
| Signaling strength |          | -32 dBm        | -79 dBm  |
| Start-up           | 0.0448 W | 0.0396 W       |          |
| Beaconing          |          | 0.0957 W       | 0.2145 W |
| Stand-by           | 0.0756 W | 0.0495 W       |          |

According to Figure 4, Figure 5, Figure 6, Figure 7, and Figure 8, we may calculate the power consumption of ZigBee and Low-Power WiFi devices, as shown in Table 1. Table 1 shows all the average power of Low-Power WiFi in three statuses are lower (49.5mW) than ZigBee (75.6mW). Comparing Figure 6 and Figure 7, we can also see that the start-up peak current of Low-Power WiFi (82mA) is higher than ZigBee (29mA).

## IV. CLOCK SYNCHRONIZATION SYSTEM ARCHITECTURE

For disaster prevention, the clock of every sensor node needs to be synchronized. In order to get more accurate time information, in this study we combined Network Time Protocol (NTP) [5] and Low-Power WiFi sensors to bring up a new clock synchronization system architecture.

Figure 9 shows the two parts in this system. The first part is an end device. The second part is an NTP server. The end device consists of a Low-Power WiFi device and an embedded device. The Low-Power WiFi device can only be configured with AT command mode through a serial port by universal asynchronous receiver/transmitter (UART) from the embedded device. Besides, data are also sent and received via AT command modes. In order to synchronize the clock on the end device, we send a time synchronizing request to the NTP server by an AT command. When the NTP server receives the request, it sends back a response. After the Low-Power WiFi device gets the clock information of the NTP server, it forwards the information to the

embedded device.

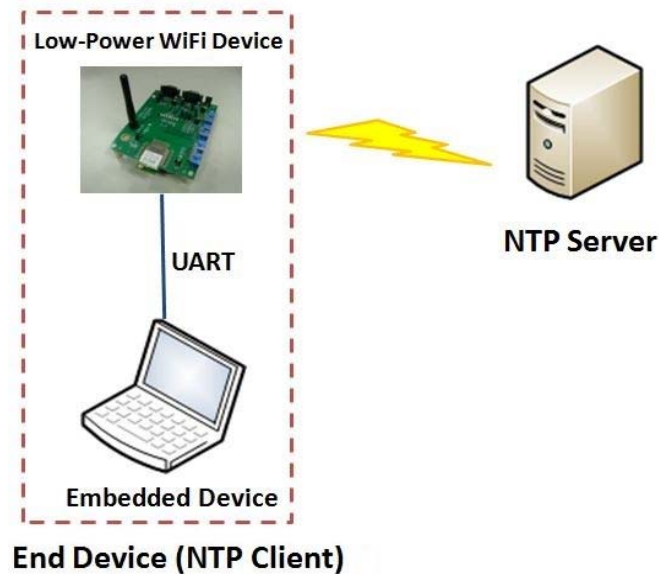


Figure 9. Clock synchronization of Low-Power WiFi devices by NTP.

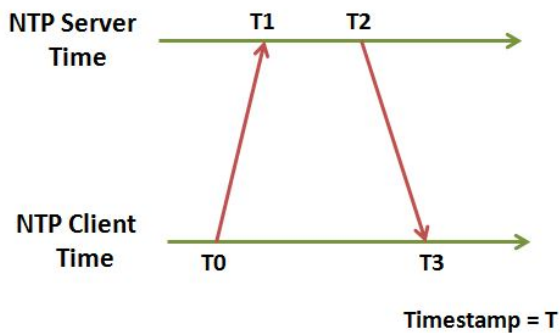


Figure 10. Clock synchronization flow with NTP.

Figure 10 shows a clock synchronization process between an NTP server and an NTP client.

- 1) **T0**: (The originate timestamp): A packet containing **T0**, which is a 64-bit timestamp specifying the local time of the NTP client, is sent to the NTP server.
- 2) **T1**: (The receive timestamp): When the NTP server receives the packet with **T0** from the NTP client, it stores the local time at this variable. If no request has ever arrived from the client, this value is zero.
- 3) **T2**: (The transmit timestamp): When the NTP server sends a packet with **T0** and **T1** to the NTP client, it generates a 64-bit timestamp specifying the packet departure time.
- 4) **T3**: The local time when the packet with **T0**, **T1**, and **T2** is received at the NTP client.

The process is repeated four times, and according to [5][6], we may calculate the average delay time and calibrate the clock time on the end device.

A program on the embedded device periodically transforms the coordinated universal time which it receives

from the NTP server, and synchronizes the clock of the Low-Power WiFi device accordingly.

## V. CONCLUSION AND FUTURE WORK

Compared with traditional WiFi equipment [3], the power consumption of Low-Power WiFi is reduced approximate 40%, which is a significant improvement. The average power consumption of Low-Power WiFi with start-up and stand-by status is lower than ZigBee, but the peak current at start-up is higher than ZigBee. Moreover, the power consumption of Low-Power WiFi device when it is receiving beacons from an AP, is twice of the power consumption at its stand-by status. If these drawbacks can be further improved, it will become a technology with great potential.

The clock synchronization usually suffers from long latency problems in wireless sensor networks like ZigBee. For the clock synchronization system we proposed in this paper, which combines Low-power WiFi devices with NTP, it would be crucial to further investigate the efficiency and accuracy of NTP packet transmission when it is applied in a Low-Power WiFi environment.

## ACKNOWLEDGEMENT

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