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Article · May 2011

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High Data Rate Wireless Sensor Networks Research

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Abstract

With the rapid development, wireless sensor networks (WSNs) are widely used in various kinds of fields. After analyzing and illustrating some limitations and disadvantages of several related research works in today's popular applications of WSNs, this paper presents some requirements of high data rate WSNs. And the paper presents the reason of choosing nRF transceiver and the modeling of nRF transceiver, which is based on our system-level simulator IDEA1.

1. Introduction

Wireless sensor networks (WSNs) is now developing rapidly and are widely used in many kinds of applications such as event detection [2], target tracking, medical and health care, and disaster exploration and sensing [1] [2].

Researches in traditional WSNs are mainly based on simple applications, which can be fully satisfied with low data rate. As of today, more and more WSNs are required to be used in such as audio and video field, large amount of data are required in the transmission in above media streaming field as well as some critical control applications, which means that high data rate WSNs is the tendency.

2. Related Works

The well known Crossbow's MICA mote, MICA2 and MICAz, for MICAz it adopts IEEE 802.15.4 standard [1] and the transmission rate are approximately 250kbps compared to MICA2's 38.4kbps, both of which are unavailable to transmit high data rate media streaming.

A Bluetooth radio with maximum data rate of 3Mbps, for example Intel iMote1 [3], which is not quite suitable for the communications with large numbers of nodes.

Panoptes [6], a video-based sensor network adopts widely used 802.11 networking. GridStix [7], used in flood monitoring and warning system can also adopt 802.11 networking. Besides, the well known Stargate1 platform can also be equipped with IEEE 802.11 cards and support high data rate applications. SensEye [8], is a new kind of WSN for its multi-tiers' architecture and using 802.11 radio to communicate with its tier2 and tier3. Generally speaking, with high power-consumption IEEE 802.11 is mainly for wireless local area network (WLAN) computer communication, but not quite suitable for WSNs.

3. High Data Rate Transceiver

Now, adopting the low power consumption and high data rate RF transceivers has become popular in many research works. First, widely used low power transceivers like CC2420 and CC1000 have been used in many works but with low data rate they don't quite satisfy with the high data rate WSNs' requirements. While in other applications some high data rate and also power-saving transceivers are used. From [10][11][12], we can see that nRF transceiver seems to be a good alternative to the above CC2420 and CC1000. Table 1 shows some characteristics for the above mentioned transceivers. With the higher data rate up to 2 Mbps compared to CC2420 and nRF2401A, nRF24L01 also has lower power consumption. With the high data rate, the probability of collision incidences is greatly reduced because of a short transmit time, which also leads to the saving of more power in the whole network. While CC2420 is a kind of 802.15.4 transceiver, nRF transceivers are equipped with embedded baseband protocol engines ShockBurst™ and Enhanced ShockBurst™ [13]. Enhanced ShockBurst™ features automatic packet assembly and timing, automatic acknowledgement and re-transmissions of packets. And for nRF24L01 which can use Enhanced ShockBurst™ not only enable the implementation of ultra low power, high performance communication with low cost host microcontrollers, but also can be backward compatible with other 1 Mbps nRF transceivers using only ShockBurst™. In addition, the nRF24L01 also offers an innovative MultiCeiver™ function which can support up to six simultaneously communicating wireless devices under the same frequency channel. This makes it ideal for building wireless Personal Area Networks in a wide range of applications [13] [14].

Radio	Data Rate (kbps)	Band (MHz)	Sleep (µA)	RX (mA)	TX (mA)
CC1000	76.8	433-915	0.2	9.3	10.4
CC2420	250	2400	1	18.8	17.4
nRF2401A	1000	2400	0.9	19	13
nRF24L01	2000	2400	0.9	12.3	11.3

Table 1. The current consumption of CC2420, CC1000, nRF2401A and nRF24L01

4. IDEA1: System-Level WSN Simulator

After comparing different high data rate transceivers, we find that nRF24L01 from Nordic can provide satisfying data rate and power consumption and we decide to use it in our system-level simulator IDEA1 [4],

which is based on SystemC Network Simulation Library (SCNSL) [5] alpha library. SystemC is chosen as the modeling tool because it can provide the co-design of HW/SW at system level and SCNSL is a free simulation kernel of Networked Embedded Systems, written in SystemC and C++, SCNSL includes five main modules: Node, NodeProxy, Network, Stimulus and Timer, which are shown in [4]. In IDEA1, SCNSL is deeply modified and improved also with some newly added radio propagation models.

In addition, a GUI (graphical user interface) is designed for IDEA1 to make the whole system easy to configure and make the network topology and simulation results visualized [4]. Users can use it to analyse the performance of the network such as packet delivery rate, transmission lactency and power consumption. Figure 1 shows the GUI.

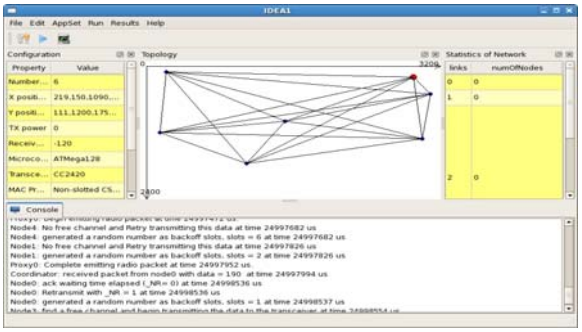

Figure 1. Graphical user interface of IDEA1: A network with 6 nodes and 1 coordinator is modeled

The hardware device library of IDEA1 supports two microcontrollers ATMega128 and PIC16LF88, three transceivers CC1000, CC2420 and MRF24J40, as well as three modes in MAC layer of IEEE 802.15.4, which includes Non-beacon mode with CSMA-CA, Beacon mode with slotted CSMA-CA, Beacon mode with GTS.

Now, the functional modules of newly added RF transceiver nRF24L01 has been basically implemented in IDEA1, and suitable communication protocols will also be applied for this transceiver. The finite state machine of nRF24L01 is briefly presented in Fig. 2. As the majority of complexity modules are intentionally designed to reside within the on-chip nRF24L01, so MCU's cost will be greatly reduced.

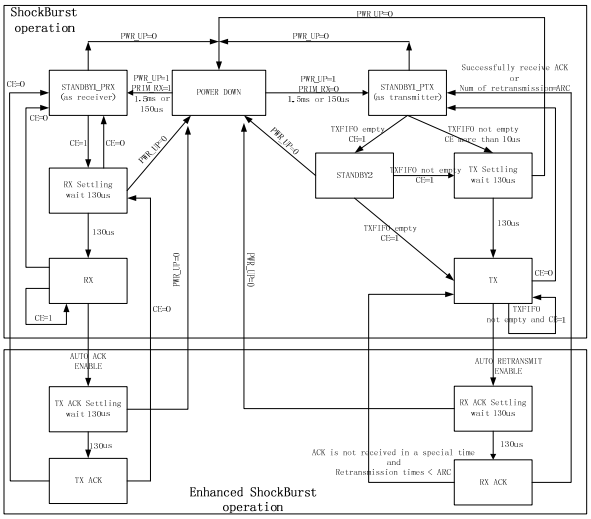

Figure 2. Model of nRF24L01 RF transceiver

5. Conclusion

In that paper, we first give a brief description of WSNs including its applications, characteristics, constraints and the desire for high data rate WSNs in modern application. Then some related works in recent years are listed. After that, according to the requirements of high data rate WSNs, the paper talks about the reasons of choosing nRF transceiver in details and the modeling of the nRF transceiver in our SystemC-based system-level simulator IDEA1 is presented.

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