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An Architecture Comparison between a Wireless Sensor Network and an Active RFID System

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Abstract

In this paper a new hardware platform for active RFID and wireless sensor network is presented. Furthermore a comparison of these two architectures is performed, i.e., the singlehop and the multihop architecture. The comparison reveals important issues regarding the utilization and energy consumption for the singlehop as well as for the multihop architecture.

I. Introduction

The Free2move [1] wireless sensor node, figure 1, is based on a transceiver operating in the 2.4 GHz ISM band. The node was initially thought of as an active RFID tag [2] for monitoring temperature in goods. However, it has been shown that it is also possible to use it as a wireless sensor network node [3]. The node is equipped with an extremely low power micro controller, Microchip PIC16F87 [4], for executing communication protocols and sensor functionality. The memory and processing resources are very limited to keep the price and energy consumption as low as possible. The node is equipped with a temperature sensor.

Figure 1: The sensor node.

The microcontroller has the following properties:

- Program flash 4 K x 14
- Data memory 368 x 8
- Data EEPROM 256 x 8
- Current low power mode 1.8 μ A (32 KHz at 2 V).
- Current, running mode, 7-9 μ A (32 KHz at 2 V).
- Current, running mode, 76 μ A (1 MHz at 2 V).
- Current, sleep mode, 0.1 μ A.

The transceiver is a Nordic VLSI nRF2401 single chip 2.4GHz transceiver [5] and is equipped with shock burst technology. This means that the data can be clocked into the transceiver at much lower clock rate than the actual transmission speed, i.e., the data is buffered in a FIFO before transmission. Transceiver specific data:

- 0 dBm maximum output power
- Output power control is between -20 – 0 dBm.
- -90 dBm receiver sensitivity
- Approximate range of 30 m
- Current @ -20dBm output power 8.8 mA.
- Current @ -5dBm output power 10.5 mA.
- Current @ 0dBm output power 13 mA.
- Current in receive mode 18 mA.
- Supply voltage 1.9-3.6 V.
- Current in power down mode 1 μ A.
- Current in stand by mode 12 μ A.

From the above data one can see that the constant current used during a transmission, is asymptotically approaching 8 mA. This amount of current is always consumed during transmission independent of the transmission output power. In receive mode the current is 13 mA.

II. Energy consumption distribution

The two architectures considered for comparison are; the *single gateway - singlehop architecture* and the *single gateway - multihop architecture*. A simple model is used for comparison. The model is based on a number of assumptions: (1) the sensor nodes and the gateway are uniformly distributed over a circular surface, (2) these are statically placed, (3) a single gateway is assumed for the extraction of the information from the network, (4) the nodes are divided into shells with discrete radius, to the gateway and these are numbered. The radius, r , can only take on a discrete value $R = \{1, 2, 3, 4, 5 \dots\}$. Sensor events generated are uniformly spread over all nodes. In both architectures, all information extracted from the sensor nodes must go through the gateway. The nodes in range of the gateway are introducing the upper bound on the information

extraction capacity of the network, defined as one capacity unit (CU).

Figure 2. Node distribution model, circular surface.

To compare the two architectures the transceivers' range in the multihop architecture is used as a reference, figure 2, this range is given as a distance unit (DU). The surface area is the same for both architectures. One area unit (AU) is equal to the circular area with the radius of one DU. AUs are expressed in π square distance units [π (DU)²]. The nodes are divided into shells in our case five. The radius, r , of each shell has a discrete value $R = \{1, 2, 3, 4, 5, \dots\}$ expressed in DUs. Each *individual shell area*, A_r , is calculated as: $A_r = \pi r^2 - \pi(r-1)^2 = \pi(2r-1) \approx 2r-1$, $A = \{1, 3, 5, 7, 9, \dots\}$ expressed in AUs. The *discrete node utilisation distribution function* for the singlehop architecture is $F_U(r) = 1/A_{tot}$. Where $A_{tot} = \sum(A_r)$ which gives $F_U = \{1/25, 1/25, 1/25, 1/25, 1/25, \dots\}$. For the multihop architecture the *discrete shell load generation density function*, $f_L(r)$, is first calculated according to $f_L(r) = A_r/A_{tot}$, which gives, $f_A = \{1/25, 3/25, 5/25, 7/25, 9/25\}$. In order to take the relaying of information into account the traffic generated in outer shells must be added. This is done by calculating the *discrete shell load*

distribution function, $F_L(r) = \sum_{i=r}^{\max \text{ nr. of shells}} f_A(i)$, which

gives $F_L = \{1, 0.96, 0.84, 0.64, 0.36\}$. To compare the individual nodes utilisation for the two architectures the *discrete node utilization distribution function*, $F_U(r)$, for the multihop architecture is calculated according to $F_U(r) = F_L(r)/A_r$ which gives $F_U = \{1, 0.32, 0.17, 0.091, 0.04\}$. For the multihop architecture, F_U , directly reflects the *discrete node energy consumption distribution function*, P_E . In the singlehop architecture we must take into account the path loss for nodes with a radius above one DU. PE is calculated according to $P_E(r) = r^2 F_U(r)$ which gives $P_E = \{0.04, 0.16, 0.36, 0.64, 1.0\}$. If the total energy consumption, P_{tot} , of all nodes for the singlehop architecture are considered we first have to calculate the *discrete shell energy distribution function*, $P_{EST}(r) = P_E(r)A_r$, which gives $P_{EST} = \{0.04, 0.48, 1.8,$

$4.48, 9.0\}$. Then we sum these elements up which gives a P_{tot} of 15.8 for the single hop architecture. The P_{EST} for the multihop architecture is actually equal to F_L . If we sum up these element we get a $P_{tot} = 3.8$. This shows that the single hop architecture has a total energy consumption that is, $P_{tot}(\text{single})/P_{tot}(\text{multi})$, 4.16 times larger. However, in the multihop architecture a sensor node in shell 1, in a five shell multihop architecture has a 25 times higher energy consumption than a sensor node in shell 5. It is the intense relaying of messages in the inner shell that cause the nodes' with worst case energy consumption. In the *singlehop architecture* the energy consumption is 25 times higher for sensor nodes in shell 5 compared to the sensor nodes in shell 1. This is a result of the higher transmission output power in the outer shells. If the sensor nodes are powered by battery this means that the nodes highest energy consumption will stay up for a period 25 times less than the nodes with the lowest *energy consumption*.

III. Conclusion

The position of the nodes with worst case energy consumption is actually opposite for the two different architectures. Of course our model is a very coarse approximation since the path loss exponent often is larger than two, which favour the multihop architecture. On the other hand the energy consumption overhead when considering the constant current consumption during transmission and reception is not taken into account in this model, which favours the singlehop architecture.

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