Effect of the Aggregate Queue and Transmit Duplicate Layers on the WSN Routing Protocols for MICA and MICAz

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Abstract

In this paper, we simulate and comparatively analyze the sensor network protocols with additional aggregate queue and transmit duplicate layers on MICA and MICAz platform with different radio models using PROWLER and RMASE. The simulation results show that the MICAz motes give low latency, high throughput, high energy consumption, low efficiency but better lifetime while the MICA motes give high success rate and low loss rate. It has been, thus, concluded that in case of all the radio models the MICA is preferably better than MICAz in applications where energy is a constraint otherwise MICAz is better as it gives greater lifetime.

Keywords: *Constrained flooding, real-time search, adaptive tree, aggregate queue, transmit duplicate, wireless sensor networks*

1. Introduction

Wireless sensor networks (WSNs) contain hundreds or thousands of sensor nodes equipped with sensing, computing and communication abilities. Each node has the ability to sense elements of its environment, perform simple computations, and communicate among its peers or directly to an external base station (BS) [1].

Routing in sensor network, however, has very different characteristics than routing in traditional communication networks. Much research has been done recently on routing mechanisms in wireless sensor networks. It has been studied that in the layered routing architecture [2], different routing components can be used to form a routing protocol. The architecture allows sharing of common components by different algorithms. In the Aggregate Queue (Agg) layer, maximum N packets may be assembled into one packet before sending. At the receiving end a packet is dissembled to N packets. Using Transmit Duplicate (Dup) component, each packet carries a zero age field the first time it is heard. The age field is incremented every time the packet is transmitted. The older the age, the lower the priority. Packets in the transmit queue are ordered by the priorities. Packets reaching the maximum age are dropped. In the literature, however, it has been found that the performance of WSNs with various routing protocols has not been carried out in the presence of realistic fading models. In this work, we have developed and integrated a new realistic radio model with Rician fading into the simulator Prowler. Consequently, the effect of the Agg and Dup layer on the performance of routing protocols has been studied in the presence of realistic radio models.

Thus the main contribution of this paper is performance analysis and comparisons of routing protocols Constrained Flooding (CF) [3], Real-Time Search (RTS) [4] and Adaptive Tree (AT) [5] for wireless sensor networks in a simulated environment for

MICA and MICAz on MATLAB platform. The comparison has been done on the basis of various performance metrics throughput (data packets/sec), average energy consumption and lifetime (years). Here the performance evaluation is done by means of simulations using event-driven simulator PROWLER (Probabilistic Wireless Network Simulator) [6] and RMASE (Routing Modeling Application Simulation Environment) [7], an application built on PROWLER.

The paper is organized as follows. Section 2 describes the simulation model used. Section 3 compares performances in case of normal radio model (NRM), radio model with SINR (RMSINR); radio model with Rayleigh fading (RMRYF); and radio model with Rician fading (RMRCF) for MICA and MICAz. Section 4 concludes the paper.

2. Simulation Model

PROWLER is an event-driven tool that simulates the nondeterministic nature of the communication channel and the low-level communication protocol of the wireless sensor nodes [6]. It can incorporate arbitrary number of nodes on arbitrary and even dynamic topology. It models all the important aspects of the communication channel and the application. The tool is implemented in MATLAB, thus it provides a fast and easy way to prototype applications, and has nice visualization capabilities. Thus, we decided to use the prowler simulator in this work instead of other network simulators available such as TOSSIM, NS2 and OPNET. The present study uses the MAC layer communication model and the radio propagation models: NRM, RMSINR & RMRYF provided by PROWLER as well as RMRCF integrated by us [8].

3. Results and Discussions

We use a real application Pursuer Evader Game (PEG) to test the performance of the protocols. In our tests, the network is a 7x7 sensor grid with small random offsets. The maximum radio range is about $3d$, where d is the standard distance between two neighbor nodes in the grid [8]. The radio data rate is 40 kbps [9] and each packet has 960 bits. On the other hand, for MICAz motes the radio data rate is 250 kbps [10] with each packet having 960 bits. The application sends out one packet per second from the sources. The results are based on 1 random run.

3.1. Case 1: Constrained Flooding (CF)

Figure 1(a) shows that the throughput of the CF protocol with Agg & Dup layer in case of MICA is 0.73 data packets/sec initially which then increases to 0.84 data packets/sec for NRM stabilizing at simulation time of 13 sec. However, in case of MICAz, (Figure 1(b)), the throughput for NRM is 0.93 data packet/sec initially which varies till simulation time of 13 sec and stabilizes at 0.90 data packets/sec. For RMSINR the throughput is 1 data packet/sec initially in case of MICA which then fluctuates to stabilize at 0.94 data packets/sec at simulation time of 12 sec. However, in case of MICAz, the throughput is 1.06 data packets/sec initially and later on varies to stabilize at 0.89 data packets/sec at simulation time of 14 sec for RMSINR. For RMRYF the throughput in case of MICA is 0.67 data packets/sec initially and stabilizes at 0.80 data packets/sec at simulation time of 13 sec. However, in case of MICAz, the throughput is 1.05 data packets/sec initially which fluctuates to stabilize at 0.86 data packets/sec at simulation time of 12 sec for RMRYF.

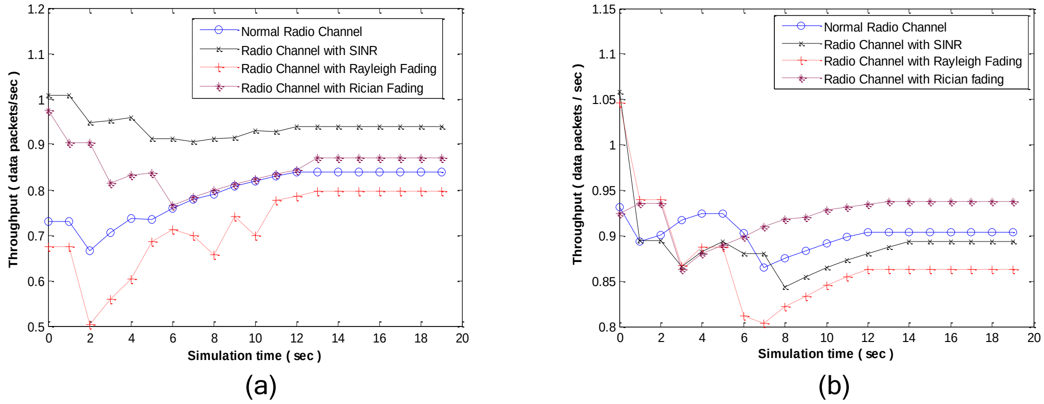


Figure 1. Average Throughput of Sensor Nodes for Different Radio Models in Case of Constrained Flooding Protocol with Agg & Dup layers (a) MICA (b) MICAz

For RMRCF the throughput in case of MICA is 0.98 data packets/sec in the beginning and varies till simulation time of 13 sec to become constant at 0.87 data packets/sec. In case of MICAz, the throughput is 0.92 data packets/sec initially and fluctuates till simulation time of 13 sec stabilizing at 0.94 data packets/sec for RMRCF. Thus, in case of CF with Agg & Dup layer, it has been observed that the RMRYF shows the lowest throughput for MICA as well as MICAz. However, the RMRYF and RMRCF indicate the highest throughput in case of MICA and MICAz respectively.

Figure 2(a) shows that the energy consumption of the CF protocol with Agg & Dup layer in case of MICA is 110 initially which then increases sharply to 440 at simulation time of 13 sec stabilizing thereafter for NRM. However, in case of MICAz, (Figure 2(b)), the energy consumption for NRM is 540 initially which then increases steeply till simulation time of 12 sec and stabilizes at 1270. For RMSINR the energy consumption is 190 initially in case of MICA which then rises to 570 at simulation time of 12 sec and stabilizes. However, in case of MICAz, the energy consumption is 390 initially and later on increases to stabilize at 1030 at simulation time of 14 sec for RMSINR.

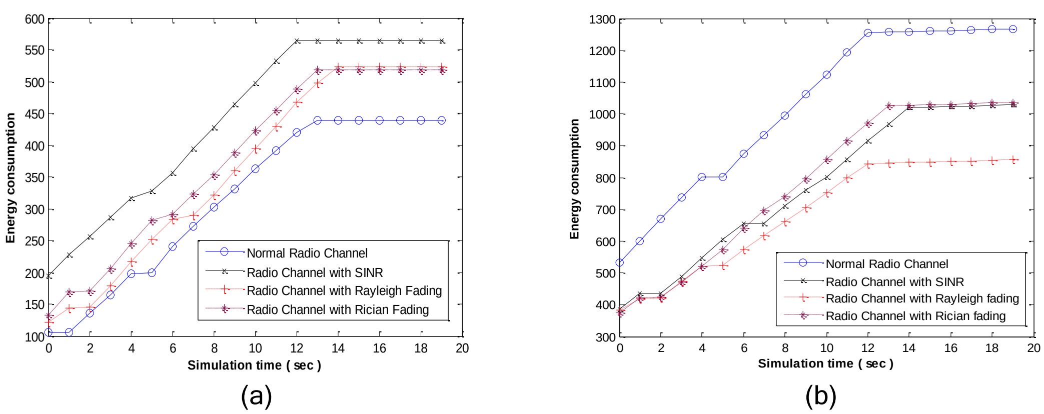
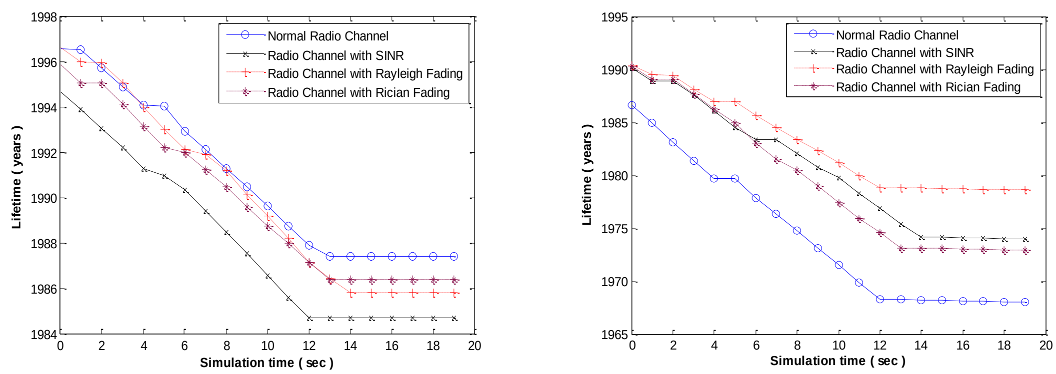


Figure 2. Average Energy of Sensor Nodes for Different Radio Models in Case of Constrained Flooding Protocol with Agg & Dup Layers (a) MICA (b) MICAz

For RMRYF the energy consumption in case of MICA is 120 initially and stabilizes at 520 at simulation time of 14 sec. However, in case of MICAz, the energy consumption is 390 initially which increases to stabilize at 850 at simulation time of 12 sec for RMRYF. In case of RMRCF, the energy consumption is 130 in the beginning and varies to become constant at 520 at simulation time of 13 sec for MICA. While in case of MICAz, the energy consumption falls in the range of [380-1040] for RMRCF. Thus, in case of CF with Agg & Dup layer, it has been noticed that the RMSINR shows the highest and the NRM indicates the lowest energy consumption in case of MICA. However, for MICAz the NRM and the RMRYF depict highest and lowest energy consumption respectively.

Figure 3(a) indicates that the lifetime of the CF protocol with Agg & Dup layer in case of MICA is 1996.5 years initially and decreases to 1987.5 years till simulation time of 13 sec and stabilizes for NRM.



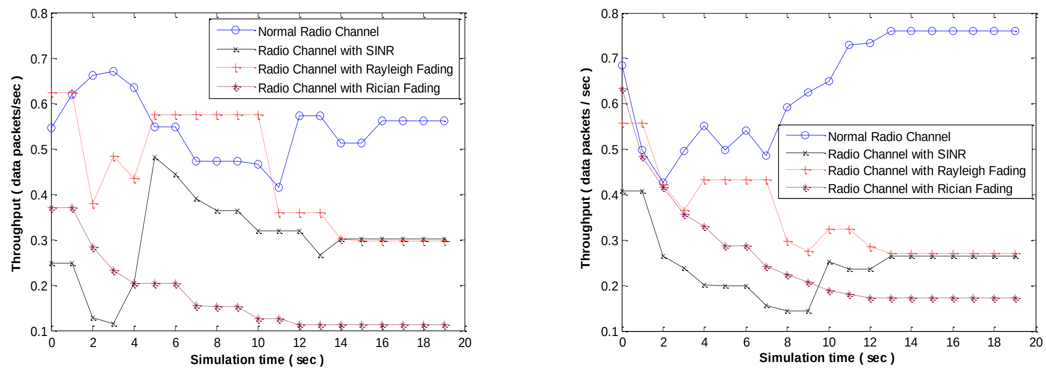
(a) (b)

Figure 3. Average Lifetime of Sensor Nodes for Different Radio Models in Case of Constrained Flooding Protocol with Agg & Dup layers (a) MICA (b) MICAz

In case of MICAz, (Figure 3(b)), the lifetime for NRM is 1987 years initially which then decreases steeply till simulation time of 12 sec when it stabilizes at 1968 years. For RMSINR the lifetime is 1995 years initially in case of MICA which then decreases to 1985 years at simulation time of 12 sec and stabilizes. However, in case of MICAz, the lifetime is 1990 years initially and later on decreases to stabilize at 1974 years at simulation time of 14 sec for RMSINR. For RMRYF the lifetime in case of MICA is 1996.5 years initially and stabilizes at 1986 years at simulation time of 14 sec. However, in case of MICAz, the lifetime is 1990 years initially which decreases to stabilize at 1979 years at simulation time of 12 sec for RMRYF. In case of RMRCF, the lifetime varies in the range of [1996-1986.5] & [1990-1973] years for MICA and MICAz respectively. Thus, in case of CF with Agg & Dup layer, it has been observed that the NRM shows the highest and the RMSINR indicates the lowest lifetime in case of MICA. For MICAz the lifetime is lowest and highest in case of NRM and RMRYF respectively.

3.2. Case 2: Real-Time Search (RTS)

Figure 4(a) depicts that the throughput of the RTS protocol with Agg & Dup layer in case of MICA is 0.55 data packets/sec initially and varies till simulation time of 16 sec stabilizing at 0.57 data packets/sec for NRM. However, in case of MICAz, (Figure 4(b)), the throughput for NRM is 0.68 data packets/sec initially which then varies till simulation time of 13 sec stabilizing at 0.76 data packets/sec. For RMSINR protocol the throughput is 0.25 data packets/sec initially in case of MICA which then fluctuates to stabilize at 0.30 data packets/sec at simulation time of 14 sec. However, in case of MICAz, the throughput is 0.41 data packets/sec initially and later on varies to stabilize at 0.26 data packets/sec at simulation time of 13 sec for RMSINR. For RMRYF the throughput in case of MICA is 0.62 data packets/sec initially and stabilizes at 0.30 data packets/sec at simulation time of 14 sec. However, in case of MICAz, the throughput is 0.56 data packets/sec initially and then varies to stabilize at 0.27 data packets/sec at simulation time of 13 sec for RMRYF.

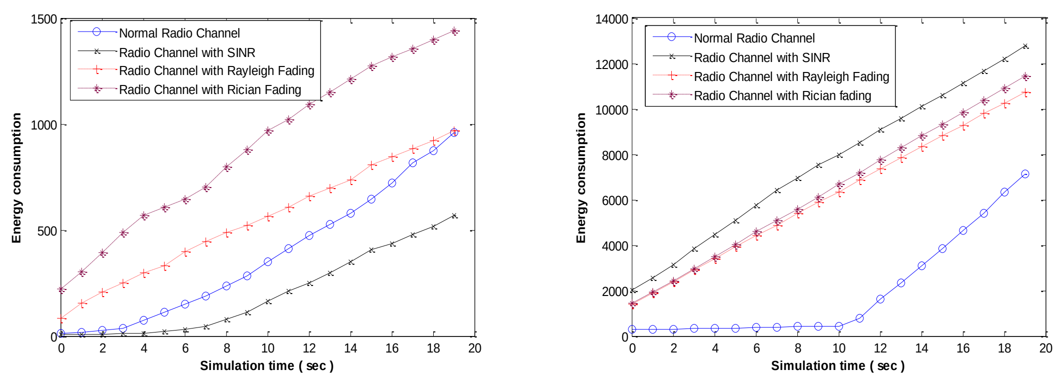


(a) (b)

Figure 4. Average Throughput of Sensor Nodes for Different Radio Models in Case of Real-Time Search Protocol with Agg & Dup Layers (a) MICA (b) MICAz

In case of RMRCF, the throughput varies in the range of [0.37-0.11] & [0.64-0.17] data packets/sec for MICA and MICAz respectively. Thus, in case of RTS with Agg & Dup layer, it has been concluded that the NRM shows the highest and the RMRCF indicates the lowest throughput for MICA as well as MICAz.

Figure 5(a) depicts that the energy consumption of the RTS protocol with Agg & Dup layer in case of MICA is zero initially which then increases sharply to 900 at simulation time of 19 sec after which it stabilizes for NRM.



(a) (b)

Figure 5. Average Energy of Sensor Nodes for Different Radio Models in Case of Real-Time Search Protocol with Agg & Dup Layers (a) MICA (b) MICAz

However, in case of MICAz, (Figure 5(b)), the energy consumption for NRM is 500 initially which then increases steeply till simulation time of 19 sec and stabilizes at 7000. For RMSINR the energy consumption is zero initially in case of MICA which then rises to 600 at simulation time of 19 sec and stabilizes. However, in case of MICAz, the energy consumption is 2000 initially and later on increases to stabilize at 13000 at simulation time of 19 sec for RMSINR. For RMRYF the energy consumption in case of MICA is 100 initially and stabilizes at 900 at simulation time of 19 sec. However, in case of MICAz, the energy consumption is 1500 initially which increases to stabilize at 11000 at simulation time of 19 sec for RMRYF. In case of RMRCF, the energy consumption varies in the range of [200-1400] & [1500-11500] for MICA and MICAz respectively.Thus, in case of RTS with Agg & Dup layer, it has been concluded that the RMRCF shows the highest and the RMSINR indicates the lowest energy consumption in case of MICA. However, the RMSINR and the NRM indicate the highest and the lowest energy consumption in case of MICAz.

Figure 6(a) shows that the lifetime of the RTS protocol with Agg & Dup layer in case of MICA is 1999 years initially and decreases to 1962 years till simulation time of 19 sec stabilizes thereafter for NRM. However, in case of MICAz, (Figure 6(b)), the lifetime for NRM is 1990 years initially which then decreases steeply till simulation time of 19 sec stabilizing at 1820 years. For RMSINR the lifetime is 1999 years initially in case of MICA which then decreases to 1975 years at simulation time of 19 sec and stabilizes. However, in case of MICAz, the lifetime is 1940 years initially and later on decreases to stabilize at 1600 years at simulation time of 19 sec for RMSINR. For RMRYF the lifetime in case of MICA is 1995 years initially and stabilizes at 1945 years at simulation time of 19 sec.

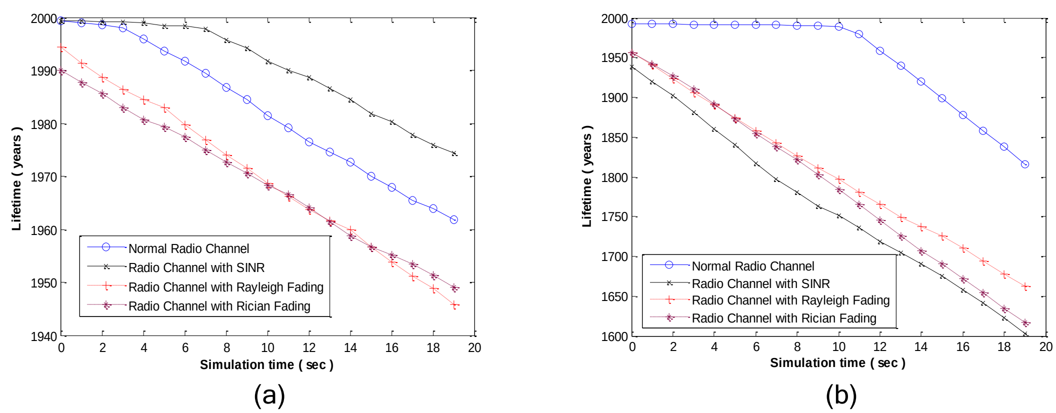
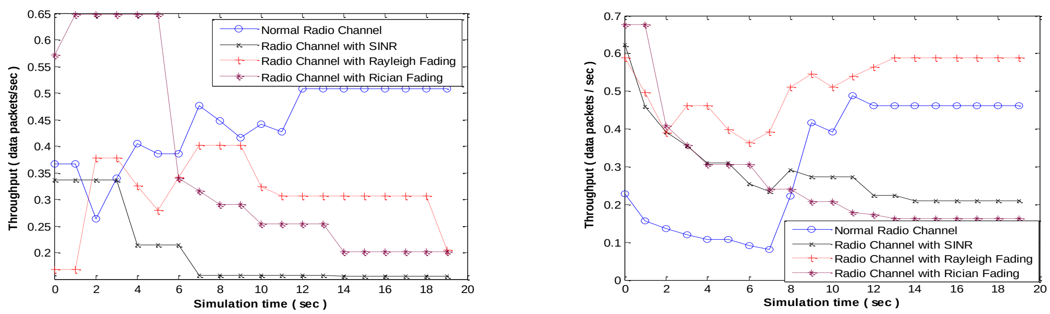


Figure 6. Average Lifetime of Sensor Nodes for Different Radio Models in Case of Real-Time Search Protocol with Agg & Dup Layers (a) MICA (b) MICAz

However, in case of MICAz, the lifetime is 1950 years initially which decreases to stabilize at 1660 years at simulation time of 19 sec for RMRYF. In case of RMRCF, the lifetime varies between [1990-1949] & [1950-1620] years respectively for MICA and MICAz. Thus, in case of RTS with Agg & Dup layer, it has been noticed that the RMRYF shows the lowest and the RMSINR indicates the highest lifetime in case of MICA. However, in case of MICAz, the NRM and the RMSINR depict the highest and the lowest lifetime.

3.3. Case 3: Adaptive Tree (AT)

Figure 7(a) indicates that the throughput of the AT protocol with Agg & Dup layer in case of MICA is 0.365 data packets/sec initially which then varies till 0.51 data packets/sec at simulation time of 12 sec after which it stabilizes for NRM. However, in case of MICAz, (Figure 7(b)), the throughput for NRM is 0.23 data packets/sec initially which then fluctuates till simulation time of 12 sec stabilizing at 0.46 data packets/sec. For RMSINR the throughput is 0.34 data packets/sec initially in case of MICA which then varies to stabilize at 0.11 data packets/sec at simulation time of 7 sec. However, in case of MICAz, the throughput is 0.62 data packets/sec initially and later on fluctuates to stabilize at 0.21 data packets/sec at simulation time of 14 sec for RMSINR. For RMRYF the throughput in case of MICA is 0.14 data packets/sec initially and stabilizes at 0.30 data packets/sec at simulation time of 11 sec. However, in case of MICAz, the throughput is 0.59 data packets/sec initially which varies to stabilize at 0.59 data packets/sec at simulation time of 13 sec for RMRYF.

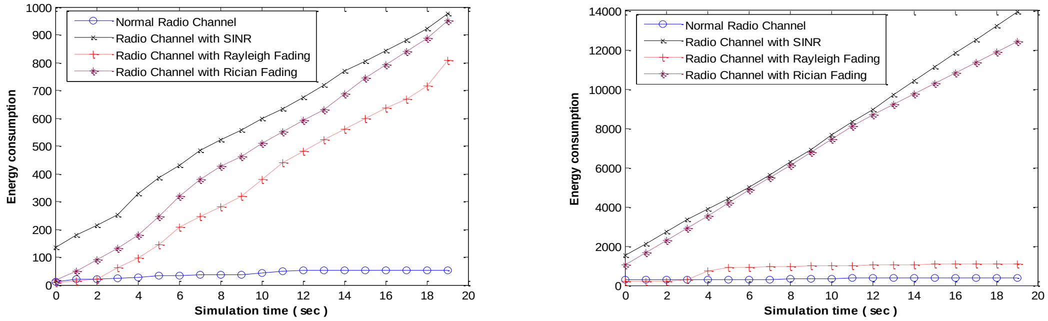


(a) (b)

Figure 7. Average Throughput of Sensor Nodes for Different Radio Models in Case of Adaptive Tree Protocol with Agg & Dup Layers (a) MICA (b) MICAz

In case of RMRCF, the value of throughput varies in the range of [0.57-0.20] & [0.68-0.17] data packets/sec for MICA and MICAz respectively. Thus, in case of AT with Agg & Dup layer, it has been observed that the NRM shows the highest and the RMSINR indicates the lowest throughput in case of MICA. However, the throughput is highest for RMRYF and lowest for RMRCF in case of MICAz.

Figure 8(a) indicates that the energy consumption of the AT protocol with Agg & Dup layer in case of MICA is 10 initially which then increases to 50 at simulation time of 12 sec after which it stabilizes for NRM. However, in case of MICAz, (Figure 8(b)), the energy consumption for NRM is 500 initially stabilizes at 510 at simulation time of 12 sec. For RMSINR the energy consumption is 140 initially in case of MICA which then rises to 980 at simulation time of 19 sec and stabilizes. However, in case of MICAz, the energy consumption is 1500 initially and later on increases to stabilize at 14000 at simulation time of 19 sec for RMSINR. For RMRYF the energy consumption in case of MICA is 10 initially and stabilizes at 810 at simulation time of 19 sec. However, in case of MICAz, the energy consumption is 500 initially which increases to stabilize to 1000 at simulation time of 14 sec for RMRYF. In case of RMRCF, the energy consumption varies in the range of [10-950] & [1000-12500] for MICA and MICAz respectively.

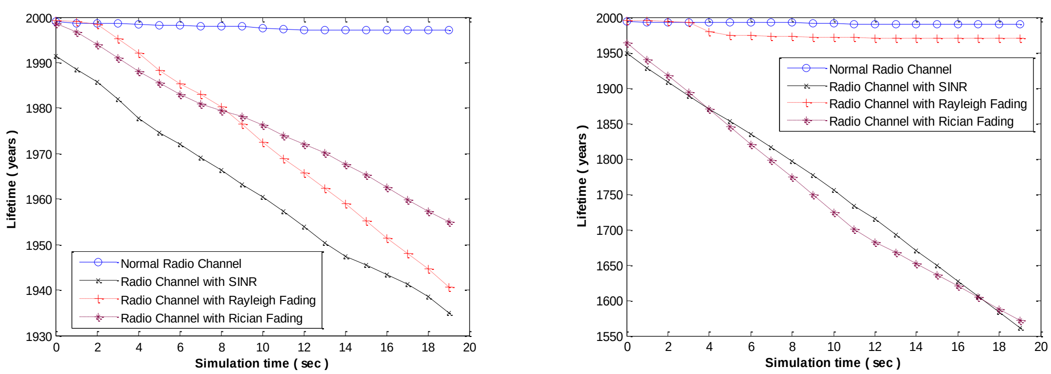


(a) (b)

Figure 8. Average Energy of Sensor Nodes for Different Radio Models in Case of Adaptive Tree Protocol with Agg & Dup Layers (a) MICA (b) MICAz

Thus, in case of AT with Agg & Dup layer, it has been observed that the RMSINR and NRM show the highest and lowest energy consumption in case of MICA as well as MICAz.

Figure 9(a) depicts that the lifetime of the AT protocol with Agg & Dup layer in case of MICA is 1999 years initially and decreases to 1997 years at simulation time of 12 sec stabilizing thereafter for NRM. However, in case of MICAz, (Figure 9(b)), the lifetime for NRM is 2000 years initially which then decreases steeply till simulation time of 9 sec and stabilizes at 1990 years. For RMSINR the lifetime is 1991 years initially in case of MICA which then decreases to 1935 years at simulation time of 19 sec and stabilizes. However, in case of MICAz, the lifetime is 1950 years initially and later on decreases to stabilize at 1560 years at simulation time of 19 sec for RMSINR.



(a) (b)

Figure 9. Average Lifetime of Sensor Nodes for Different Radio Models in Case of Adaptive Tree Protocol with Agg & Dup Layers (a) MICA (b) MICAz

For RMRYF the lifetime in case of MICA is 1999 years initially and stabilizes at 1940 years at simulation time of 19 sec. However, in case of MICAz, the lifetime is 2000 years initially which decreases to stabilize at 1970 years at simulation time of 5 sec for RMRYF. In case of RMRCF, the value of lifetime varies between [1999-1955] & [1960-1570} years respectively for MICA & MICAz. Thus, in case of AT with Agg & Dup layer, it has been concluded that the RMSINR and the NRM show the lowest and the highest lifetime in case of MICA as well as MICAz.

4. Conclusions

In this paper, the simulation results of the comparative investigation of the performance of routing protocols CF, RTS and AT for wireless sensor networks with additional Agg and Dup layers using different radio models have been presented. The simulation results show that in case of CF protocol with Agg & Dup layer the NRM gives lower lifetime with more energy consumption and the RMRYF gives better lifetime with lower energy consumption for MICAz motes. In case of MICA motes, the NRM gives better lifetime and low energy consumption in contrast to fewer lifetimes and high energy consumption provided by RMSINR. Moreover, the RMRYF shows fewer and RMSINR gives longer lifetime in case of MICA motes and RMSINR and NRM indicate fewer and higher lifetime for MICAz motes in case of the RTS protocol with Agg & Dup layer. Further, in case of the AT protocol with Agg & Dup layer, the RMSINR and the NRM depict less and highest lifetime for MICA and MICAz motes respectively. Moreover, amongst the three protocols the lifetime in case of the AT protocol with Agg & Dup layer is better than the CF and the RTS protocol with Agg & Dup layer.

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