Multihop Routing in Camera Sensor Networks: An Experimental Study

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1. INTRODUCTION

Camera sensor networks have received considerable attention in recent years. While the traditional wireless sensor networks (WSN) consist of low-bandwidth sensors with limited capabilities, e.g., acoustic, vibration, and infrared sensors, camera sensor networks can provide visual verification, in-depth situational awareness, recognition, and other capabilities ([1], and references therein).

Similar to the traditional WSNs, camera sensor networks communicate using the low-bandwidth wireless channel, such as IEEE 802.15.4; and often in-network information processing is emphasized. But a number of applications require infrequent transmissions of images over wireless using multihop routing. The effects of the burstiness of camera sensor networks are often unpredictable and can cause troubles when using camera sensor networks. In order to design a more effective camera sensor network system, it is desirable to understand and study network behaviors when transmitting data from camera sensors over multihop. Such a study can provide us with optimal operating settings and a guideline for application developers.

In this paper, we report findings from multihop routing experiments using camera sensor networks, which were conducted as part of our on-going research in camera sensor networks. Our camera sensor network consists of CITRIC camera motes [1] and TelosB motes [2].

Our finding shows that there is a tradeoff between the reception rate and latency at different levels of network traffic. A more interesting finding is that adding a delay between packet transmissions can improve both the transmission rate and the end-to-end reception rate.

2. EXPERIMENT SETUP

CITRIC Mote: A CITRIC mote consists of a camera daughter board connected to a TelosB board. The camera daughter board contains a low-voltage 1.3 megapixel SXGA CMOS image sensor (OmniVision OV9655) and a PXA270 microprocessor running embedded Linux.

Multihop Routing: The Collection Tree Protocol (CTP) is a tree-based address-free multihop routing protocol[1]. CTP is chosen for our experiments because of its high data throughput compared to other multihop protocols currently available for TinyOS. For our experiments, we modified the routing engine of CTP and fixed the path from a source CITRIC mote to the base station such that we can study the behavior of the network at fixed numbers of hops.

Setup: A CITRIC mote is used as a leaf node that transmits image data and TelosB motes serve as intermediate nodes between the CITRIC mote and the base station. A 60 KByte image is transmitted from a CITRIC mote; the image size is based on the average size of 640x480 JPEG color images of an urban scene taken from CITRIC motes. All the motes are placed in close proximity. Hence, the number of hops in our experiments can be also interpreted as a level of network congestion.

Two different sets of experiments have been conducted by varying the payload size and the delay between packet transmissions. Experiments are repeated for different hop counts: 1–5, 7, 9, and 11 hops[2]. For the first set of experiments, we used 25, 50, 75 and 100 bytes of payloads based on the fact that the maximum packet size of CC2420 MAC layer is 128 bytes, which include a header of 25 bytes (CTP, CC2420, and CITRIC mote specific header fields). The delay between packet transmissions at the CITRIC mote is varied in the second set of experiments: 0 (best effort), 40, 80, 120, and $160ms$. We found that $160ms$ is the maximum interval since retransmissions are rarely observed at this interval.

3. EXPERIMENT RESULTS

We measured data transmission rates (amount of data received at the base station divided by the transmission time), end-to-end reception rates (ratio of the number of packets received at the base station to the total number of packets sent from the CITRIC mote), and image transfer latencies (average time to receive an image at the base station)[3] at different settings.

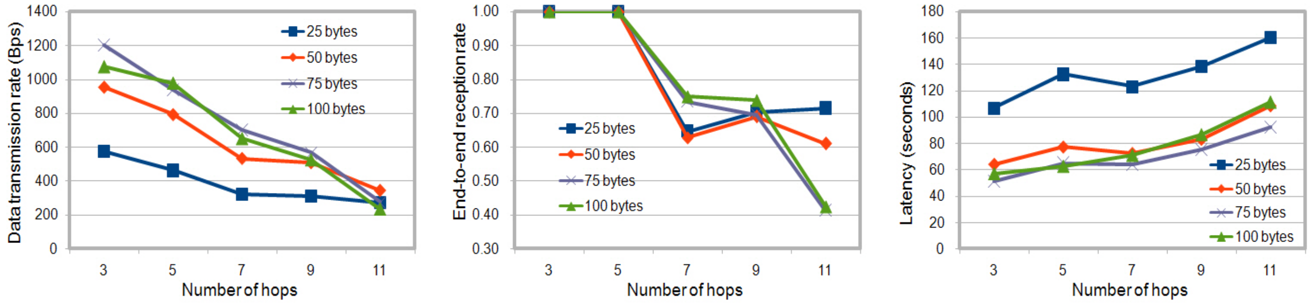
Payload Size: Figure 1(a) shows data rates at different hop counts for different payload sizes. It shows that the data rate drops with increasing hop counts. The payload size of 100 bytes shows a slightly lower data rate at 11 hops.

The end-to-end reception rate shown in Figure 1(b) decreases significantly as the hop count increases. In general,

[1] TEP 123: The Collection Tree Protocol `http://www.tinyos.net/tinyos-2.x/doc/html/tep123.html`

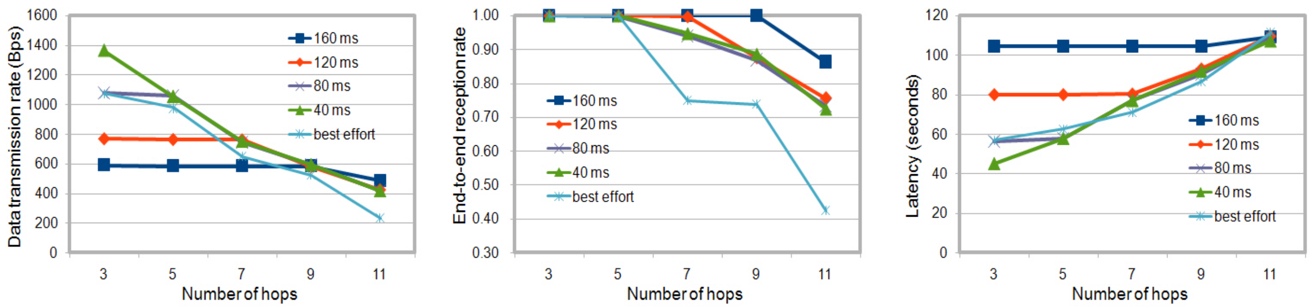
[2] Results from 1, 2, and 4 hops are not shown here since their performance is similar to the case with 3 hops.

[3] A small latency does not necessarily mean a high data transmission rate since fragments of an image can be dropped.



(a) (b) (c)

Figure 1: Network performance at different payload sizes at $0ms$ (best effort) transmission delay. (a) Data rate as a function of hop counts. (b) End-to-end reception rate as a function of hop counts. (c) Latency as a function of hop counts.



(a) (b) (c)

Figure 2: Network performance at different delays between packet transmissions with a 100-byte payload. (a) Data rate as a function of hop counts. (b) End-to-end reception rate as a function of hop counts. (c) Latency as a function of hop counts.

the reception rates for all payload sizes decrease as the hop count increases. A larger payload will take more time to transmit and the chance of collision increases, hence the reception rate decreases. For a smaller payload size, more packet transmissions are required to transmit an image and increases the chance of collision. This also decreases the reception rate. While the figure shows a higher reception rate at the higher hop count for smaller payload sizes, we plan to perform additional experiments at even higher hop counts to observe the trend more clearly.

The image transfer latencies for different payload sizes are shown in Figure 1(c). As expected, our results show that there is a tradeoff between the reception rate and latency at different hop counts, i.e., different levels of network traffic.

Delay Between Packet Transmissions: In this experiment, we varied the delay between packet transmissions at the CITRIC mote.

As shown in Figure 2(a), the best effort is not the best approach in a multihop network in terms of data transmission rate; a delay of $40ms$ consistently performs better than the best effort. It can be observed that the data rate starts to drop at different hop counts for different delays. It shows that the delay between packet transmissions can be optimized based on the network density.

Figure 2(b) shows that the reception rate drops at smaller hop counts with shorter delays. Especially, the best effort yields less than a half reception rate at 11 hops. This result can be used to find the shortest transmission delay time with a desired latency without reducing multihop network's reliability.

In Figure 2(c), it shows that, for all delays, the latency increases as the hop count increases. However, at 11 hops, they all show the same latency.

4. REFERENCES

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