Near real time network simulation for team sports monitoring

Daniel A. James\textsuperscript{a,b,d*}, Lino Fanella\textsuperscript{a,c,d}, Roberto Cusani\textsuperscript{c}

\textsuperscript{a}Centre for Wireless Monitoring and Applications, Griffith University, Nathan, Qld 4111, Australia
\textsuperscript{b}Centre of Excellence for Applied Sport Science Research, Queensland Academy of Sport, Sunnybank, Qld, Australia
\textsuperscript{c}Dipartimento di Ingegneria dell’Informazione, dell’Elettronica e delle Telecomunicazioni (DIET), Facolta’ di Ingegneria dell’Informazione, Informatica e Statistica, Università di Roma ”La Sapienza”, Via Eudossiana 18, Italy
\textsuperscript{d}Queensland Sports Technology Cluster, Brisbane Australia

Abstract

On field monitoring of athlete performance is a growing area of interest in elite, professional and even some amateur sports. Metrics routinely monitored can be tactical, physiological and biomechanical, some methods are more labor intensive than others such as bloods and video coded and hand scored performance data. More recently the introduction of wearable sensors and GPS have allowed comparatively large amounts of data to be collected. These sensors are changing the way athletes are assessed, and today are routinely used by a number of professional football codes. Near real time systems, have been shown to enable the information to be accessed more quickly and thus the data can be used tactically, for workload management during game play, in addition to post game analysis. One of the major challenges is to have robust wireless network solutions for this challenging environment. This paper implements a number of player based network topologies and protocols in a simulation environment to test various scenarios, as a tool for future development. Performance limitations to throughput and goodput are used to identify potential bottlenecks. Because the construction of physical hardware devices for athletes and networks, simulation is an attractive process that can shorten development time, identify and solve design problems more rapidly. These tests are intended as an input to designing better devices, networks and thus optimizing ambulatory systems for range, battery life and size reduction.

© 2013 The Authors. Published by Elsevier Ltd. Selection and peer-review under responsibility of RMIT University

Keywords: Real time; wireless; sports monitoring; work load; simulation
1. Introduction

Traditionally athlete performance monitoring is performed in the laboratory where the required instrumentation is available and performance conditions are recreated and controlled. In such conditions, the athletes maybe quasi static (such as rowing machines, treadmills) and so does not always permit a realistic analysis of the performance expected in the field, nor reproduce the actions of skill based activities. To undertake performance evaluation of the athlete in real time in the natural performance environment is an important goal. The ability to monitor athletes during their training activities has emerged in recent years, pushing to the limit of engineering developments in the clinical-medical and sports engineering fields [1].

One of the major obstacles encountered so far has mainly concerned the difficulty of having wearable devices, able to acquire important physiological [2] and biomechanical data, but without interfering with normal behavior of the athlete [3]. In the last few years, thanks to the advancing in microelectronic, embedded micro-controllers and wireless networking technologies, there has been a growing use of wireless sensor networks in performance analysis so as to allow the laboratory to move directly on the training camp or even during competition.

The potential of wireless sensor network integrates seamlessly with the increasing computational capabilities made available in portable devices (e.g. handheld computers) in order to design appropriate systems for perfect portability [4] and low cost data processing[5]. Typical acquisition and processing of sensor data has acquisition rates of up to 100 samples for tri axial accelerometer, tri axial gyroscope and GPS data stream. Timeliness of feedback is an important consideration and near real-time feedback is preferred for many applications.

In this paper a test bed wireless sensor network application is devised, it includes consideration of a typical team sports deployment, a sample payload of accelerometer and gyroscopes sensors as a tool for a near real-time wearable systems for monitoring and active control on physical performance for application such as multiple athlete team sport. We describe the design of a wireless sensor network using the standard IEEE 802.11 [6] and we perform a series of simulations to evaluate the impact of number of users and application packets size on the performance of 802.11b transmissions in terms of goodput, packet loss and Transmission Control Protocol and User Datagram Protocol (TCP/UDP) choices. Throughput is the most common network-level metric. It is the data amount sent by sender. However, we use goodput instead of throughput for performance presentation because total data amount received is more important to most end users than that sent by sender.

A balance between timeliness and efficiency of the network is an important consideration. Real time feedback has great value in both the coaching and training environment and has been greatly facilitated by the advent of low cost wireless technologies [7]. Wireless technologies have advanced considerably in recent years giving rise to many communications protocols that target different balances between throughput, power consumption and complexity. Many of these protocols are open standard whilst other proprietary standards are vying for market share with competing manufacturers.

2. Wireless network technology

Wireless sensor networks (WSN) have a wide variety of applications like domestic application, medical application, safety application for vehicle, and military systems [8]. Typical challenges for WSN are large scale, constantly changing network topologies, and error prone communications. WSN nodes have limited processing and storage capacities, as well as energy resources. Most often WSNs are demanded to be robust against environmental strains, and able to autonomously recover from error...
situations. Further, depending on the applications and the interaction with environment, time synchronization and security requirements can be strict [6].

There are essentially two approaches to develop a wireless sensor network. Utilize a proprietary protocol solution for the specific application or use a standard communication protocol [9]. Existing protocols reduce the development time of a wireless sensor network considerably and more time can be dedicated to analysis of the retrieved data, however a custom design can create a more specific and hence better overall solution. Given project lifespan for many research endeavors it is likely that any chosen technology will be updated and out of date or obsolete by the time any working network is complete. This is an important consideration when choosing between a stable technology from a well-known manufacturer or developing a cutting edge or novel technology. New protocols must be upgraded regularly whereas existing protocols will be developed and supported by the manufacturer.

Existing wireless protocols can again be divided into two different categories; global standards ratified by a standards body and proprietary wireless networks implemented by a single company. The risk of using proprietary radio standards to implement a wireless sensor network solution is that support and supply of radios can be limited if only one company produces them. Conversely ratified standards are passed by members from many companies which ensure that the specification is robust and usually ensures that many vendor options are available.

The IEEE 802.11 technology has become the most deployed wireless technologies in the entire world. The main characteristics of the 802.11 Wireless Local Area Network (WLAN) technology are simplicity, flexibility and cost effectiveness. This technology provides people with a ubiquitous communication and computing environment in offices, hospitals, campuses, factories, airports, stock markets etc. One application of the IEEE 802.11 is in the field of wireless sensor networks. These networks consist of variable mobility, low-power, wireless nodes, sensing real-time data. The sensors may monitor the performance of an athlete such as physical performance [10]. In this application sensors capture and transmit a near real-time stream to an aggregation point or party interested in viewing the stream else where in the network. The aggregation point or interested viewer may not be reachable directly, i.e., via a one-hop wireless transmission, from the sensor. The stream may have to be forwarded by multiple wireless hosts along the way from the source sensor to the destination viewer. There are several factors in ensuring usable quality of the real-time stream transmitted to the viewer in this manner including hops, contention, Quality of Service (QoS) and noise.

Within the IEEE standard and many other standards are differing transport protocols. In the IEEE 802.11s standards TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) are the most commonly transport protocols used. TCP provides a reliable connection and is used by the majority of current Internet applications, UDP is a simpler protocol with less error checking and thus considered to be more temporarily accurate.

TCP, besides being responsible for error checking and correcting, is also responsible for controlling the speed at which this data is sent. TCP is capable of detecting congestion in the network and will back off transmission speed when congestion occurs. These features protect the network from congestion collapse.

UDP focuses more on near real-time communications. Near Real Time communication has the advantage of not requiring a completely reliable transport level. The loss of small percentage packets or bit errors will often only introduce minor break in the output. For these reasons most near Real Time applications use UDP for the data transmission.

3. Simulation

The simulation environment is designed to resemble a typical team sports environment. The number of mobile nodes (athletes) are varied from 2-50 and allowed to move within a simulated 100m x 100m
boundary using a free walk algorithm. The physical field size of 100mx100m, approximates world football dimensions and that of many other sports. It is modeled smaller than the transmission range of individual radios so that every station in such field can communicate directly with every other station. Thus transmission medium degradations are accounted for, these are due to multipath fading or interference from nearby nodes reusing the same physical-layer characteristics can cause some stations to appear ‘hidden’ from other stations. Consequently, a collision occurs if two or more hidden nodes start transmission simultaneously for the same receiver.

Typical performance characteristics from manufacturers specifications and measured characteristics are used to define model parameters [11]. In our study we use an UDP application to stream the athlete’s physical data to the aggregation point were the data can be processed and analyzed. We conduct a series of simulations in order to determine the performance of the WSN in terms of goodput and packet loss with respect to the number of nodes and the packet data size. Simulation are conducted using OmNet++ simulation [12].

Variables investigated include operation mode, number of nodes(athletes) and data payload, with performance being defined through goodput

4. Results

The simulations were designed to high light network performance degradation by varying parameters to network failure and compare the performance of ad-hoc and infrastructure modes under these conditions. Two experiment are conducted firstly, we vary the load rate of the network by increasing the number of nodes from 2 to 50 keeping a fixed packets size and in the second simulation we have increased packets size while maintaining the fixed number of nodes.

Fig. 1.(a) shows the real-time traffic goodput of the network working in infrastructure mode, while varying the number of the nodes in the network. It can be observed that when the number of the nodes is larger than 10, the performance of the network decreases drastically. This effect is shown also in Fig 1.(b) where packet loss to total network failure (100%) is shown against number of nodes.

Clearly goodput drops severely with the increase of the nodes. There are two main causes for this behavior: Firstly, in order to send a packet from the source to the server, the same packet has to be
retransmitted twice; secondly because the Access Point (AP) has the same priority as a normal wireless node.

Without any rate control, as in UDP, the traffic from all senders will easily fill up the buffer of the AP, and a large portion of the packets will be dropped by the AP. In fact, once the aggregation offered load is larger than half of the system bandwidth, the AP will not be able to forward the entire incoming packet in time. Such traces can be confirmed also from the statistics of packets drop in the AP collected during the simulation. The percentage of the packets drop in the AP is from 75% to 95% of the total packets loss when there are 5-10 nodes. Thus once the offered load per nodes is beyond the threshold, the whole system will be saturated and the real traffic sent out by each nodes will became a constant. In this configuration, the AP is the bottleneck of the network. Results like this help identify bottlenecks and solutions, such as connecting the AP by wire to the server can solve this problem. In this configuration wasn’t considered as the design constraints were for a fully wireless environment.

Fig. 2(a) shows the experiments of the near real-time goodput of the network working in Ad-Hoc mode. In this case we can see that the performance increasing until 15-20 nodes and then the goodput is almost the same result even though the offered load of the network increases.

In Fig. 2(b) it can be seen that as the number of the nodes increases, the packet loss rate grows almost linearly depending of the packet size. We also notice that the smaller packet size leads to a better loss rate respect to the bigger size. The results of both investigation show that IEEE 802.11b achieve near real-time goodput when the network traffic load is low and, also when the traffic increases, the network is not able to handle all the amount of that data.

5. Conclusions

In this paper, we presented a promising simulation technique for performance evaluation of WiFi networks fed by near real-time traffic for sporting applications. By running a set of simulations on an operative network, we derived some interesting guidelines for the setting of the topology of the network and packet application parameters. Results obtained while analysing the goodput and the packet loss experienced by IEEE 802.11b under different condition show that the protocol can be employed in wireless sensor network if the number of the device is limited and/or the near real time traffic is limited too. In particular, for a number of devices below 10 and with real time traffic packet size below 1280 Bytes both network mode can support traffic generated by near real-time application. For network with a
higher number of station (>10) and with real time traffic packet size below 1280 Bytes is more performance using ad hoc mode.

As future work, we plan to extend the measurement parameters considering more realistic traffic scenarios and compare the simulation with a real wireless sensor network. Its is also planned to undertake more complex simulation using historically gather data sets and evaluate node based compression. Additionally the simulation environment offers the opportunity to consider newer protocols such as IEEE 802.11e, n and others in the 802.x family as a low cost alternative to construction and testing. Thus the tool can save on development time and allow quicker development time with enhanced success rates.

Acknowledgements

The authors acknowledge the financial support of Università di Roma "La Sapienza" for the financial support of Fanella to undertake a visiting fellowship at Griffith University and the support of Griffith University for hosting

References

[1] Sutherland, J, Searching for the holy grail; Wallabies athlete load monitoring, Sport Health, 2011;29(3) (pp52-55) Sports Medicine Australia: Australia
[4] Rowlands, D, James, DA, Architectures for iPod/iPhone applications in field sports, Procedia Engineering 2006;2 (2), 3493-3493