Ubiquitous Sensor Networks Traffic Models for Image Applications

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Abstract. The Internet of Things (IoT) is a new concept for telecommunication development. The IoT and things determinations are considering in accordance the ITU-T recommendations. The Ubiquitous sensor Network (USN) is one of the general IoT components. The traffic models for such network should be studied well. The USN traffic models study results for image applications are considered in this paper. The USN in the paper will be not special for image transmission. This USN is multi application network with AODV (Ad Hoc On-Demand Distance Vector) signalling protocol. The paper results show that the traffic flows for image USN applications are self-similar with the high level of self-similarity.

Keywords. IoT, USN traffic, image applications, Hurst parameter

1 Introduction

The 7 trillion wireless telecommunication units for 7 billion people could be form the network at 2017-2020 in according with forecast [1]. Moreover, the estimation of the total number of things that could be connected with the future networks is 50 trillion (up to 5000 things for every human) [2]. Therefore the future networks will be self-organizing and the most important traffic sources will be things.

The Internet of Things (IoT) is the new ITU-T concept for the network development. The ITU-T determines IoT as a future global infrastructure: “In a broad perspective, the IoT can be perceived as a vision with technological and societal implications. From the perspective of technical standardization IoT can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies”[3, 4]. Things are considered as things from the nature and information worlds.

The IoT will be based on the Ubiquitous Sensor Network (USN) [5]. So the USN traffic models should be studied well. Unfortunately, now there is no much researching activity in this area. The Poisson arrival process was assumed as traffic model for each individual sensor node in [6]. The ON/OFF method [7] for USN traffic models was analyzed in [8]. Authors proved that ON period distribution and OFF period distribution could be described by generalized Pareto distribution. The pseudo long range dependent (LRD) traffic model was proposed in [9] for mobile sensor networks. The USN traffic models was studied for telemetry applications in [10] and for medical and tracking applications in [11], where the Hurst parameter estimations were determined.

There are many USN classifications. The appendix 1 to [12] determines the USN classification by such objects characteristics as size, mobility, power, connectivity, ability, people involvement, physical/logical objects, object with tag, IP/non-IP. The USN classification by application groups based on traffic characteristics was proposed in [10]. The following USN traffic classes are considered: voice, signalling, telemetry, images, reconfiguration, local positioning.

The image applications are very special for USN in according with the necessary data capacity for transmission and rates, of course. The are many investigations which proposed difference image compressions methods for efficient image transmission in USN [13,14,15]. All of this methods could be used for special USN, named visual sensor networks or camera sensor networks [16,17]. The traffic investigation for camera sensor networks revealed that the traffic for similar networks could be modelling by semi-Markov chain [17].

The multi applications USN we studying in this paper and a widely used JPEG will be considered as the compression method. The video amount of data per frame were studied well and have been fit to lognormal, gamma, and Pareto probability distributions or combinations of them [18]. The image amount of data will be determined in the paper by statistical analysis of acceptable Internet photos.

2 Network model

It's not useful to use sensor networks exclusively for digital image transferring. If we look at the most probable application for such techniques - it is intrusion alarm system. In this case sensors, installed on network nodes, controlling certain parameters and in case of event (for example sensor triggering) transferring digital image of controlled area to operator. Most of time such networks will be in stand-by mode so it's appropriate to use them for telemetry data collection.

Nodes of modelling network randomly placed on the sensor field with size 30 by 30 meters. Sink node placed in the center of the field. In case of high interference at the 2.4 GHz broadcast frequency and low power of transmission guaranteed range of data transmission is about 15-20 meters. Thereby, the proposed model adequately describes the network with minimum number of multi-hop transmission with a single node for data collection. If necessary, expand the sensor field for data collection more sink nodes can be placed in parallel.

For telemetry data collection 50 nodes randomly placed on field. Nodes send data packets with specified intervals, chosen from the range 15, 30, 45 and 60 second, randomly for each node. Additionally to data collection nodes, there are 5 nodes for digital image processing and transmission. Example of sensor nodes placement shown on figure 1. Nodes with telemetry sensors marked by green, digital image processing nodes marked by blue and central sink node marked by red.

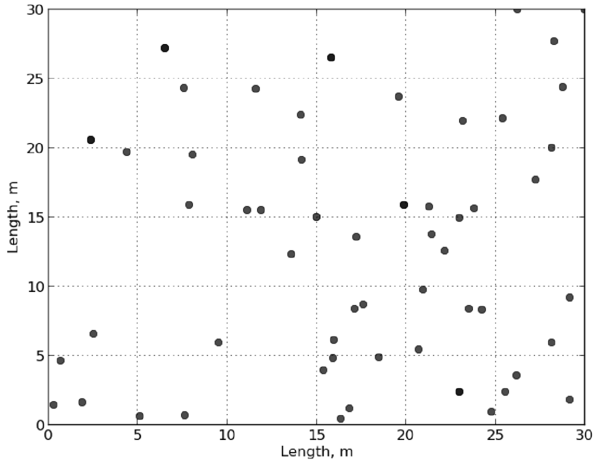

Fig. 1. Network nodes placement

3 The image amount of data probability distribution

Data transmitted by telemetry nodes can be described by short string, or signed integer, or float, thereby for its transmission enough only 4 bytes. If we look at the digital image transfer there are a lot of parameters affecting to the amount of data (or size) of result image.

Firstly we have to choose coding format. If we consider the transmission of uncompressed images then for each pixel we will need to pass 3 bytes describing the components of red, green and blue color. Thus to send a picture with pixel size of 640 by 480 pixels will require 921,600 bytes. Modern compression techniques can reduce this amount by ten times. Most compression formats, what produced smallest amount of data, based on wavelet analysis, but they require a lot of processing power, which will lead to a rapid discharge of sensor node.

Compression methods JPG and PNG were selected after considering the options. The JPG format is a lossy compression method with the changeable level of quality which varies in range from 0 to 100. In opposed to JPG, PNG format is a method of lossless compression. After analysing various options for data compression techniques for the transmission of color images was chosen JPG method with quality 25, and for the transmission of monochrome images was selected format PNG, shown the best record. The quality level of 25 is allow, as enables us to distinguish even small details.

The second most important factor influencing to the amount of data needed to be transmitted is the scene imprinted on digital image, such parameters as the area fills with one colour (such as sky), the total number of different colours, etc. To estimate the possible size were chosen for investigation one thousand images taken with different cameras and with different scenes. All images were converted to 640 x 480 pixel with different compression format. Histogram of the results amount of data distribution for colour images compressed with JPG is shown in Figure 2 and for monochrome images compressed with PNG in Figure 3.

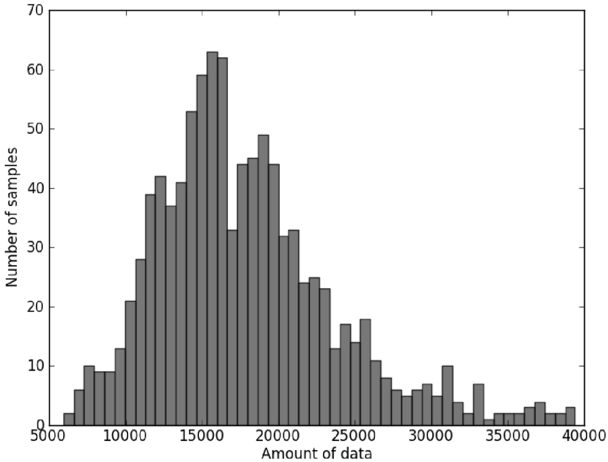

Fig. 2. Histogram of the results amount of data distribution for colour images

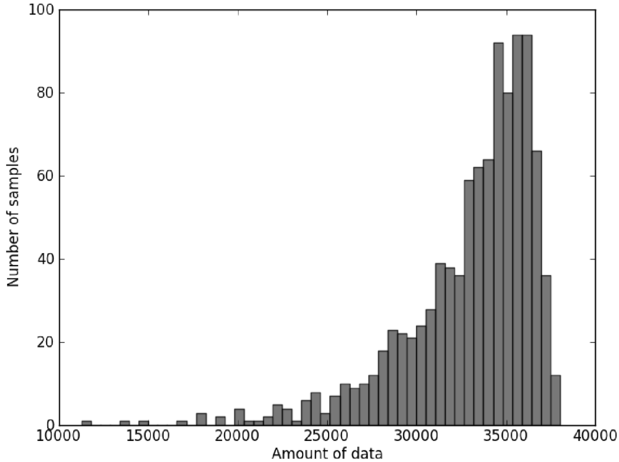

Fig. 3. Histogram of the results amount of data distribution for monochrome images

Probability density functions for this distribution described by Gamma distribution that was confirmed with Kolmogorov–Smirnov criteria.

4 Modeling results

Simulation of the proposed model was made using software system developed by the authors with open source solutions. It is based on the Network Simulator 2 package, with the Python programming language used for processes automation. As a universal language, Python has a rich standard library, as well as a huge range of modules written by third parties. In work used the library for mathematical calculations NumPy, SciPy and graph renderer Matplotlib. Transforming of digital images, as well as the calculation of the parameters of the distribution functions are also performed using the language Python, using Python Image Library.

As a base was developed NS-2 template scenario, which describes the configuration of the wireless channels, all the necessary functions, and service commands. To transmit telemetry data, and digital images were developed procedures to quickly create a connection between two nodes and connect to the source of the load with the necessary parameters.

The Python programming language script was developed for automatisation of processes, whose task is to generate random data, such as location coordinates of nodes, the start time of telemetry communication, interval between messages, the size of transmitted images, etc. Once all the data has been generated, final scenario passed to the NS-2 interpreter, for direct execution.

The result of the NS-2 work is presented in the form of Trace file containing information about all packages sent in the simulated network. Each entry contains the timestamp, packet type, source and destination addresses of the message, as well as additional overhead. Analyzing the file line by line, possible to get all the necessary information.

Aggregating data for different time periods, we can observe how the load would look on different scales, but the general shape of the load remains the same. This is one of the properties of self-similar processes, changes in the time scale is equivalent to changing of the spatial scale.

The number of packets data, received during step by step trace analyze, used to calculate the Hurst parameter, which characterizes the degree of self-similarity of the load on the network. There are several ways to estimate the Hurst exponent, in this study was chosen the most common - a method of analyzing of variance-time plot. The method consists in the study of self-similar slowly decaying variance of the aggregated process. To determine the parameter we have to calculate the slope of the fitting straight.

Considered method of analysis shown in Figure 4.

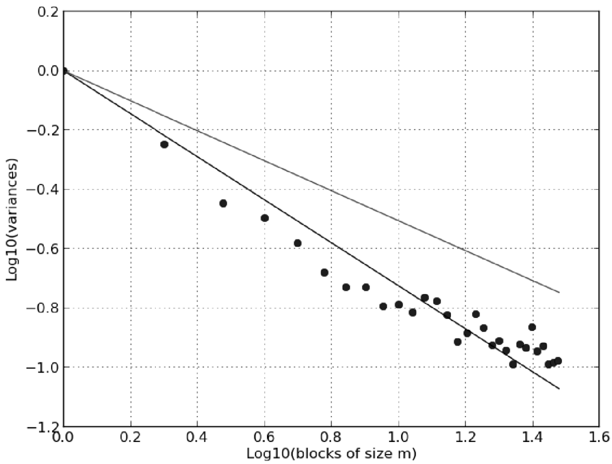

Fig. 4. Variance-time plot analysis

Hurst parameter value greater than 0.5 is considered to be a sufficient basis for the recognition of self-similar process. It should be noted that the value of H close to one, may mean that the process is deterministic, i.e. not random.

The average value of Hurst coefficient is 0.768 for colour images and 0.785 for monochrome images. This proves that the aggregate load created by the transmission of digital images in sensor networks is self-similar with a high level of self-similarity.

Based on calculated Hurst parameter possible to get autocorrelation function approximation. Graphical representation of the autocorrelation allow visually verify that the investigated flow has long range dependency. Autocorrelation shown in Figure 5.

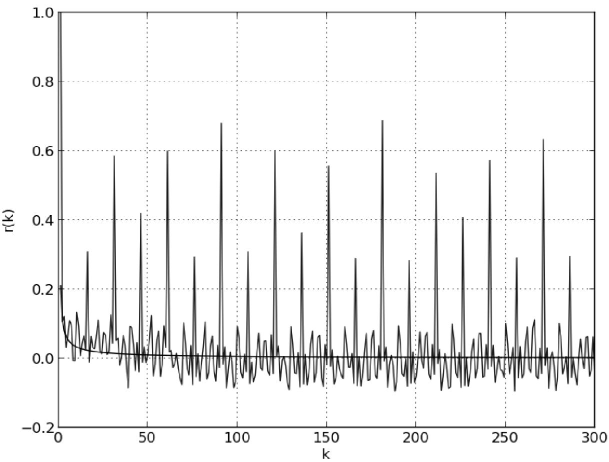

Fig. 5. Autocorrelation function approximation

5 Future work

In future investigation, authors plan to continue the research topic of digital images transmission in USN networks. In particular, it is planned:

- transition to the Network Simulator 3 package
- use of new tools of image coding, such as codec WebP
- use of a routing protocol RPL

Package Network Simulator 3 is currently being developed inherited the best of NS-2, with making a lot of innovations. The main difference of the new package is to move model scripting language from TCL to Python. At the core of the simulator as before used the C++ language.

WebP format is the youngest image compression format, it was introduced by Google two years ago, its development still continuing. Capabilities of WebP method let save the image in lossless or lossy mode. Already, the process of encoding images requires comparable compute power consumptions, but lossless image compressed at 26% smaller in size compared to PNG, and the lossy images are compressed at 25-34% less compared to JPEG.

The development of sensor networks is still going on, not so long ago, a IETF ROLL working group was released routing protocol specification RPL. This protocol is designed to work in IPv6 low power and lossy networks. The basis of the protocol is directed acyclic graph.

Each connection in the RPL network is described by set of metrics such as bit rate, power consumption, encryption support, etc., based on which acyclic graphs are created. In one network possible to create multiple graphs, and the node will transmit data depending on the purpose of the data. In such a network can be organized graph for transmission of alarm messages with minimal latency and graph for telemetry data transmission with most energy efficient way.

The appearance of RPL protocol is an important point in the development of sensor networks and the authors plan in subsequent studies to compare the results obtained in the simulation scenarios based on AODV protocol and RPL.

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