DISI – University of Trento

Master in Computer Science AA 2015/2016

Simulation and Performance Evaluation

Assignment 2 and 3 (11+11 points available)

Analysis of a simple wireless communication network

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A very simple wireless communication system is sketched in Fig. 1. A square area of normalized length 1 is given, with 10 communication nodes $n_1 \dots n_{10}$ distributed uniformly at random in the area (the red dots). Each node is equipped with an omnidirectional antenna and can transmit to and receive packets from all other nodes within a normalized communication range $r = 0.25$.

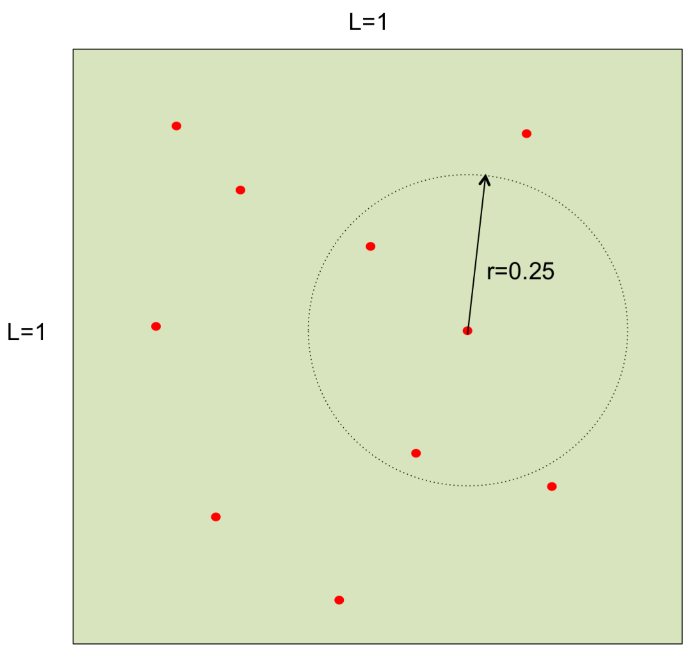

Figure 1: Simple wireless network with 10 nodes distributed at random in a unit square

The transmission speed is fixed and identical for all nodes $B = 8\,\text{Mbit/s}$. The propagation delay is negligible, i.e., it can be approximated to zero. The packet size S_p is a random variable in bytes, drawn from a distribution $f_S(s)$ identical for all nodes. Packet size respect the most common protocols limits and has a minimum packet size of 32 bytes (typical of some sensor networks) and a maximum packet size of 8192 bytes (Ethernet "jumbo frames"). The actual maximum packet size is specified by the parameter n in the dataset. The packet inter-arrival time T_p is random, drawn from a distribution $f_T(t)$ identical for all nodes. One parameter of $f_T(t)$ is not specified and must be used to change the traffic offered by the stations to the channel, so that the response of the system to a varying load can be studied.

The distributions $f_S(s)$, $f_T(t)$, the nodes positions $(x_1, y_1) \dots (x_{10}, y_{10})$, and the buffer size of the transmission queues C_b are assigned to each student similarly to what we have done for the datasets of the first assignment. Appendix A reports all the possible distributions that can be assigned in the datasets. Appendix B reports one sample dataset for reference. The true datasets are in the file `students-data.zip`; download, unzip it and search for your data in the file `surname.data`. If you don't find it send us and e-mail.

The communication protocol is extremely simple and similar to the continuous time Aloha protocol:

- All packets are sent in "local broadcast", i.e., all nodes within the communication range r from the sender will receive the packet if there are no collisions, but will not re-transmit them;
- Packets are not acknowledged;
- Two packets that "overlap" in time (also partially) at a receiver will be both lost (for that specific node), not for the others;
- If one packet is generated at a node and the node is idle (not transmitting or receiving), it is transmitted immediately;
- If one packet is generated at a node while this node is either transmitting or receiving, will be enqueued locally at the node for later transmission;
- A node start transmitting if it has a packet in its queue and it is not receiving (or transmitting) any packet.

Simulation Part

Simulate the given system evaluating:

- The throughput for each node (and the total) as a function of the average offered load (identical for all nodes and derived from $f_S(s)$, $f_T(t)$;
- The collision rate and the loss rate (in nodes buffers) for each node (and the average);
- Estimate the reliability (confidence intervals and levels) of your simulation experiments and represent them a whiskers in the plots.

Remember that using available math libraries in the language you choose is highly recommended. Don't waste your time to re-code what is already coded and tested, devote your time to the simulation coding itself and the performance analysis.

Analysis Part

Devise a simplified model of the system that can be solved analytically, then solve it and compare the results with the simulation ones. Also compare your model to the (trivial) model of the pure Aloha protocol.

Preparing the report

The report should not exceed five pages in the given format. It should include a flow chart of the simulator, and any other information useful to understand the simulator itself (e.g., algorithms or pseudo-code); do not replicate code comments. Also include a drawing of the approximated model and the equations for closed form solution.

Include additional performance measure of your choice that you think help gaining insight in the system (e.g., average queues levels).

Programming language and coding

A general purpose programming language must be used. We suggest python for its immediacy, but C, C++, and Java are also accepted. The program must run under Linux and be self-contained; code must be properly structured and commented to understand what it does (and possibly why it does it). Self-contention means that the code delivery on Classroom must be in a tarball or zipped directory, it must contain a `readme.txt` file with all necessary information for compilation and running. The tarball must contain a `Makefile` with the following two commands:
`> make` that compiles the program and prepares for running; and
`> make run` which starts the simulation and reproduces all the results that you have obtained to write the report. The latter implies that there is an input file that the program reads to run all the required replicas of the simulation experiment. The tarball should also contain the scripts used to post-process the data obtained. Be sure to use standard software in your `Makefile` for compiling, e.g., `gcc/g++` or `clang/clang++` for C/C++ and `javac` for Java (python does not need a compiler).

Good luck!

A Distributions used

Packet size $f_S(s)$

Distributions are discrete, so the actual probability $P(s)$ of the size s can be expressed.

Discrete Uniform

$$P(s) = \frac{1}{m}; \quad m = \max - \min + 1$$

The maximum and minimum size are part of the support of the distribution.

Geometric

$$P(s = k + 31) = (1-p)^{k-1}p^k; \quad k = 1, 2, \ldots n - 31$$

The distribution must be shifted so that the minimum size is 32 as expressed in the equation, and it must be properly truncated at $n = \max$, ensuring that the resulting distribution is not skewed.

Binomial

$$P(s = k + 31) = \binom{n}{k}(1-p)^{n-k}p^k; \quad k = 1, 2, \ldots n - 31$$

The distribution must be shifted so that the minimum size is 32 as expressed in the equation, and it must be properly truncated at $n = \max$, ensuring that the resulting distribution is not skewed.

Interarrival times $f_T(t)$

Continuous Uniform

$$f_T(t) = \frac{1}{T_{\max}}; \quad 0 \leq t \leq T_{\max}$$

$T_{\max}$ is the free parameter.

Exponential (Poisson Arrivals)

$$f_T(t) = \lambda e^{-\lambda t}; \quad t \geq 0$$

λ (or rate) is the free parameter.

Raileigh

$$f_T(t) = \frac{t}{\sigma^2} e^{-t^2/(2\sigma^2)}; \quad t \geq 0$$

σ (or scale) is the free parameter.

Gamma

$$f_T(t) = \frac{t^{k-1}e^{-t/\sigma}}{\sigma^k \Gamma(k)}; \quad t, k, \sigma \geq 0$$

σ (or scale) is the free parameter, the shape k is given.

Weibull

$$f_T(t) = \frac{k}{\sigma}\left(\frac{t}{\sigma}\right)^{k-1} e^{-(t/\sigma)^k}; \quad t \geq 0$$

σ (or scale) is the free parameter, the shape k is given.

B Sample dataset

The free parameter of the distribution is indicates as `param=?`.

The distribution of the packets length must be properly translated and possibly truncated in the interval $[32, 8192]$.

The assigned data looks like the following:

```
Packet size (in bytes) distribution:
Binomial(p=0.834, n=1200)Support: [32, 1232](to be rounded to the nearest integer)
Inter arrival time distribution:
Exponential(rate=?)
Node buffer size: 50
Node postitions:
Node0(0.522, 0.6);
Node1(0.487, 0.357);
Node2(0.962, 0.603);
Node3(0.677, 0.575);
Node4(0.556, 0.158);
Node5(0.693, 0.531);
Node6(0.897, 0.658);
Node7(0.311, 0.729);
Node8(0.598, 0.817);
Node9(0.207, 0.702);
```