Methods of Control for Quality Parameters of the Proposed Sensor Network

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***Abstract*—Research a narrowband channel model for WSANs is conducted. A suitable comparison between the measurements performed and some simple analytical expressions has been conducted for all environments considered: with nodes over flat ground and asphalt**

***Keywords*— control, node, quality, sensor, sink, network, probability, interference, assess, SIR, WSN**

I. Introduction

In wireless ad hoc networks the best performance is achieved, when data generated by a node can flow along the network and reach any possible endpoint. Thus the goal of connectivity is to make it possible for any node to reach any different node, perhaps in a multi-hop fashion. That provided, the network is said to be fully connected. Although WSNs are sometimes thought of as a special case of wireless ad hoc networks, they present a substantial difference, that is, nodes are at least of two different types: sensor and sink nodes. The purpose of this kind of network is to process data originated by sensors, and sinks are in charge of collecting such data. Thus, the goal of control quality parameters at connectivity is somewhat different here because it is sufficient for any sensor node to be able to reach at least one sink node, either directly or through other sensor nodes.

II. Methods of control for interference of sensor nodes

Consider a single sink two-dimensional scenario with one or more sensor nodes which attempt to establish a connection with the sink. As usual, assume nodes to be spatially distributed according to a PPP with density ρ, but this time they occupy a bounded circular domain of radius r_T. A sensor node N_1 is placed inside the domain, while a sink node N_0 is placed in the center. The propagation environment is still characterized by distance-dependent loss and log-normal channel fluctuations. However, recognize that the link connectivity model (fig.1) suffers from a serious weakness: received power alone (or, equivalently, the maximum tolerated loss) does not permit to assess whether a connection has been established or not, but also the interference must be taken into account through the SIR.

As an example, a sink that " hears " a sensor node with a maximum signal strength, might still not be able to ' understand ' what it ' says, because other sensor nodes also ' talk ' .

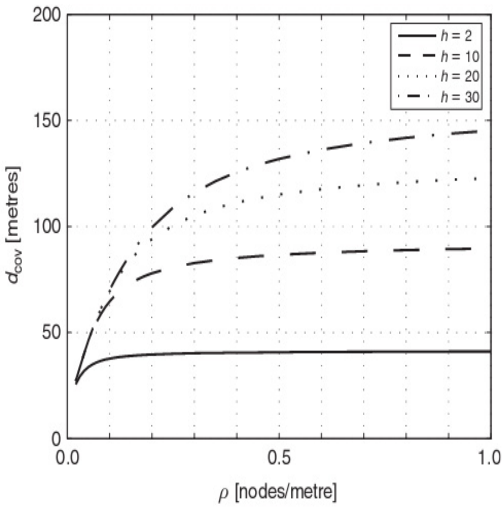

Fig. 1. Coverage distance vs node density for different number of hops *h*, target coverage probability 0.1, *σ=4*

That move towards the direction of quality of connection rather than quantity of received power by taking into account the effect of the interference (fig. 2).

First, derive the distribution of the channel gain between two communicating nodes, then can obtain an expression for the general moment of the total interference received by N_0: in this way, the SIR can also be easily computed.

III. Control channel gain characterization

Assume that all the nodes in the area transmit by using the same power P_t and that the log-normal propagation model is valid. The log-normal model is widely adopted in the literature to describe the power loss, in *dB*, between two communicating nodes:

$$L = k_0 + k_1 \cdot \ln r + S \quad (1)$$

where *S* is a shadowing sample which is assumed to be Gaussian distributed, with zero mean and standard deviation *σ,* to model the randomness of the geometry (presence of obstacles, etc.). Generally, link reciprocity is assumed and the different shadowing samples competing to different nodes are considered to be independent.

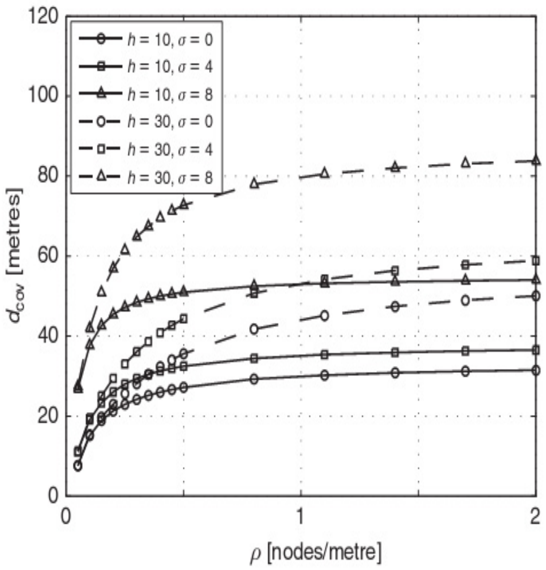

Fig. 2. Coverage distance vs node density for different number of hops h and shadowing conditions σ. Target coverage probability 0.5

Now consider that the distance between N_I and N_0 does not exceed r_T and that the two nodes are within the (random) communication range. Although the unconditioned S_B (1) is a normal, the distribution of S, conditioned on the fact that N_I communicates with N_0 is not normal. However, to simplify the analysis, we assume that the distribution of S conditioned on the fact that N_I communicates with N_0 is still normal with zero mean and standard deviation σ will show that the approximate distribution we obtain with this assumption is extremely tight.

Realization s of the S and consider the following two cases.

Case I :

$$r_T > e^{\frac{L_{th}-k_0-s^*}{k_1}} \quad (2)$$

In this case, which occurs when s $s^*>L_{th} - k_0 - k_1$ in r_T (with probability $1 - C\ (r_T)$ the maximum communication distance is less than r_T). In such a situation, the probability that the distance D between nodes is less or equal to a certain value d conditioned on $s = s*$ can be written, as

$$P\{D < d | s = s^*\} = C^{(I)} d^2, 0 \le d \le e^{\frac{L_{th}-k_0-s^*}{k_1}} \quad (3)$$

with $$C^{(I)} \triangleq e^{-2e^{\frac{(L_{th}-k_0-s^*)}{k_1}}}.$$

Therefore the joint probability distribution function - p.d.f. of the D and S is:

$$f_{D,s}^{(I)}(d, s^*) = C^{(I)} \frac{2de^{\frac{-2(L_{th}-k_0-s^*)}{k_1}} e^{\frac{-s^{*2}}{2\sigma^2}}}{\sigma\sqrt{2\pi}} \quad (4)$$

for $0 \le d \le e^{\frac{L_{th}-k_0-s^*}{k_1}}$ but $s^* > L_{th} - k_0 - k_1 in\ C^{(I)}$ is a normalizing factor that accounts for the fact that the channel fluctuation is bounded. The range of d and s * can be re-written as:

$$L_{th} - k_0 - k_1 ln r_T \le s^* \le L_{th} - k_0 - k_1$$

$$\ln d \quad 0 \le d \le r_T \quad (5)$$

Case II:

$$r_T \le e^{\frac{L_{th}-k_0-s^*}{k_1}}$$

In this case, which occurs with probability $C\ (r_T)$, the maximum communication distance is greater than r_T and the cumulative distribution function (c.d.f.) of D can be written as:

$$P\{D \le d\} = C^{(II)} d^2 = \frac{d^2}{r_T^2}, \quad 0 \le d \le r_T \ , \quad (6)$$

where $C\ (\ II\ )$ is the normalizing factor.

Therefore, the joint p.d.f. of the r.v. ' s D and S is:

$$f_{D,s}^{(II)}(d, s^*) = \frac{C^{(II)} 2de^{-(s^*)^2/2\sigma^2}}{r_T^2 \sigma\sqrt{2\pi}} \quad (7)$$

For $0 \le d \le r_T, -\infty < s^* \le L_{th} - k_0 - k_1 ln r_T$,

where now $C\ (\ II\ )$ accounts for the fact that S is bounded $-\infty$ by and $L_{th} - k_0 - k_1\ ln\ r_T$.

Making the change of variable in obtain:

$$f_{G,Y}^{(II)}(g, y) = \frac{2C^{(II)} e^{-\frac{2}{k_1}(g+k_0+y)} e^{-\frac{y^2}{2\sigma^2}}}{r_T^2 \sigma\sqrt{2\pi}} \times rect\left(\frac{e^{-\frac{g+k_0+y}{k_1}} - r_T/2}{r_T^2 \sigma\sqrt{2\pi}}\right) \quad (8)$$

For $-\infty < y \le L_{th} - k_0 - k_1 ln r_T$,

where:

$$rect(x) \triangleq \begin{cases} 1, & |x| < \frac{1}{2} \\ 0, & |x| \ge \frac{1}{2} \end{cases} \quad (9)$$

Shows that the channel fluctuations do not give any contribution on the distribution of channel gain in case of infinite plane, but play a significant role when a finite area is considered.

IV. CONTROL MEASUREMENTS OVER FLAT GROUND

Figure 3 shows the measurement scenario in this case. The devices were located h = 80 cm above flat ground. With a link range of about 21 meters, the Fresnel first ellipsoid is not obstructed by the ground and almost LOS communication might be expected. The PER is reported in fig.4, as a function of the 16 channels used. At minimum power (16.6 dBm) the PER shows values significantly larger than zero. However, these values range from zero to more than 90%. (fig.5) shows the values of received power for the same set of experiments. Having in mind that the receiver sensitivity is equal to 92 dBm, the values of average received power at minimum transmit power reported in fig.5, clearly motivate PER values above 0.01. The reason for values of PER in fig .4, much above 0.01 are to be related to the non linear relation between PER and the measured received power values which are affected by small errors caused by the measurement equipment. Let us also note that the values of received power do not change significantly when spanning the 16 channels. This is basically because there are no frequency-selective effects in such an environment and all frequencies behave in the same way. The 16 experiments at fixed transmit power (spanning the 2.4 GHz band) were conducted in a relatively short period of time (about two seconds); therefore, strong time coherence was kept between two measurements at two different frequencies.

Finally, it is worth noting that the average (over the 16 channels) values of received power, when changing the transmit power level, change significantly and not proportionally. In other words, the power loss given by the difference between the transmit power and received power in logarithmic scale is not identical in the three cases. For the maximum and nominal powers, it is about 60 dB, while at minimum power it is about 76 dB.

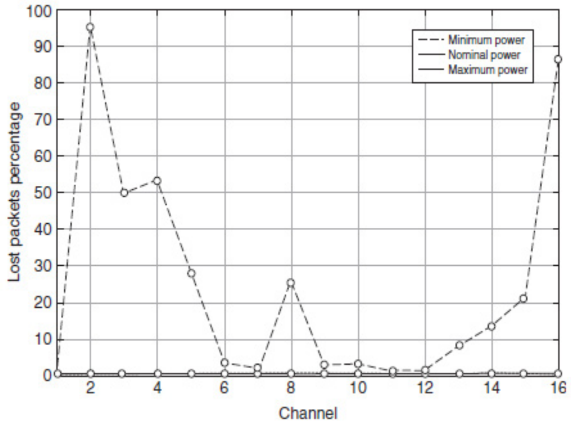

Fig. 3. PER as a function of the 16 channels over flat ground

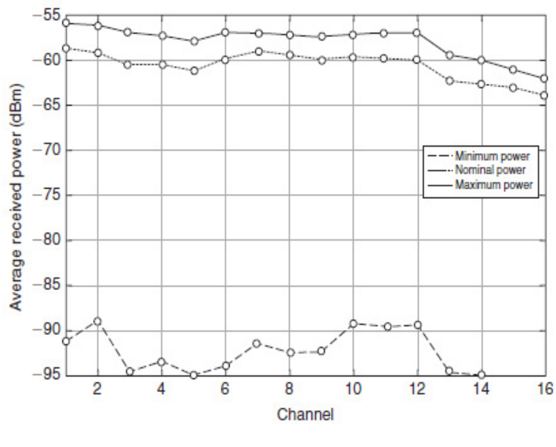

Fig. 4. Average received power as a function of the 16 channels over flat ground

The large difference is due to the fact that the three measurements were performed under the same topology, but at different times, with many seconds needed to set a new power level.

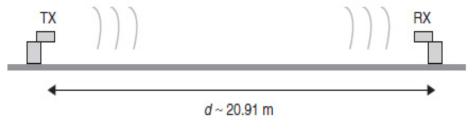

Fig. 5. Measurement scenario over asphalt

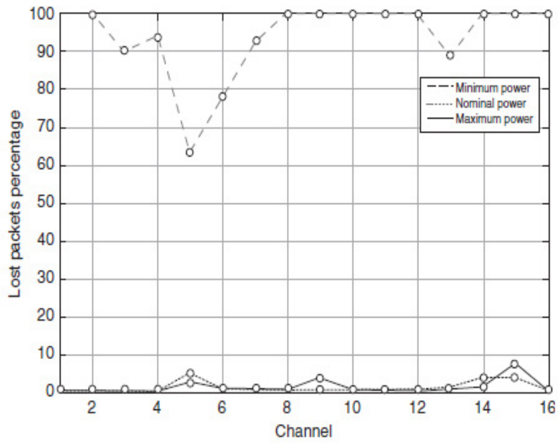

Fig. 6. PER as a function of the 16 channels over asphalt

Therefore, there is no time coherence between the three measurement.

This shows that random channel fluctuations which are not related to the link distance variations can play a very significant role. In fact, assuming 0 dB gain for both antennas, the free-space loss obtained by applying the Fries formula should be equal to about 67 dB, a value, which lies in between those measured.

The channel fluctuations in this case might be caused by the wind moving the grass, the tree leaves and the bushes that were located in the close neigh boohooed of the communication link.

V. Conclusion

Research a narrowband channel model for WSANs is conducted. A suitable comparison between the measurements performed and some simple analytical expressions has been conducted for all environments considered: with nodes over asphalt, grass, in a parking lot, and in indoor environments. It was found for the received power in logarithmic scale that in general a Gaussian model can approximate the measurements.

In general, there was no deterministic dependence on distance as testified by all measurements reported in this chapter. Some papers in the literature report results achieved in similar environments, and the Gaussian model seems to be accredited. Note that since the scenario is usually stationary, the assumption of a (slow-varying) shadowing environment is acceptable.

Connectivity in Wireless Ad Hoc And Sensor Networks. In wireless ad hoc networks the best performance is achieved when data generated by a node can flow along the network and reach any possible endpoint. Thus, the goal of connectivity is to make it possible for any node to reach any different node, perhaps in a multi-hop fashion. That provided, the network is said to be fully connected. Although WSNs are sometimes thought of as a special case of wireless ad hoc networks, they present a substantial difference, that is, nodes are at least of two different types: sensor and sink nodes. The purpose of this kind of network is to process data originated by sensors, and sinks are in charge of collecting such data. Thus, the goal of connectivity is somewhat different here because it is sufficient for any sensor node to be able to reach at least one sink node, either directly or through other sensor nodes. The connectivity theory studies networks formed by large numbers of nodes distributed according to some statistics over a limited or unlimited region of $\mathbb{R}^d$, with $d = 1, 2, 3$, and aims at describing the potential set of links that can connect nodes to each other, subject to some constraints from the physical viewpoint (power budget, or radio resource limitations). Connectivity depends on the number of nodes for unit area (nodes' density), and on the transmission power. The choice of an appropriate transmit power level is an important aspect of network design as it affects network connectivity. In fact, with a high transmit power a large number of nodes are expected to be reached via a direct link. On the contrary, a low transmit power would increase the possibility that a given node cannot reach any other node, that is, it is isolated. In the literature, the connectivity theory typically considers three types of scenarios:

- a Poisson Point Process (PPP) with intensity ρ over an unbounded region
- a square area of side L (or disk of unit radius) with nodes distributed in the region according to a PPP with intensity ρ
- a square area of side L (or disk of unit radius) with N (fixed) nodes uniformly distributed at random in the region.

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