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# Hybrid Wireless Communications with High Reliability and Limited Power Constraints in Noisy Environments

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## 1. Introduction

Recent research efforts in the area of wireless networks investigated the usage of low information capacity wireless nodes (also called "data acquisition points") integrated in a homogenous network to gather and deliver information. These low capacity nodes fall short in: (i) providing the required complexity to achieve high reliability wireless links and (ii) providing long term deployment, due to their design and power consumption. Both high reliability in the communication links and long term deployment are of paramount in most space related applications: such as monitoring in the space shuttle, international space station, and inflatable habitats.

In order to address these limitations of the present state-of-the-art, a new paradigm for wireless communication is required. A hybrid communication architecture implemented through two-tiered wireless networks is discussed in this paper. The super nodes possess more resources and are able to handle computationally complex tasks. This architecture enables the use of more efficient error correction schemes (at the physical layer) such as Turbo-like codes, which are capable of achieving channel capacity. A significant technical merit of the scheme discussed resides in achieving the highest possible reliability (arbitrarily close to the theoretical limit) by distributing the error correction into different hybrid architecture tiers. This scheme assures high link reliability, allows for low power consumption of super-nodes at the upper tier, and no-power sensor deployment in the lower tier, through the use of passive spread spectrum surface acoustic wave (SAW) interrogated units.

## 2. Two-tiered Data Acquisition System

Conventional communication networks do not take advantage of the full channel capacity, which would be possible if capacity achieving codes such as Turbo-codes were used. However the usage of turbo scheme in low capacity wireless nodes is not feasible due to limited computational resources and power availability. In turbo wireless communications systems the received signal is decoded using a soft output decoder, which provides the reliability of the data in addition to the data. This information then becomes input to a second decoder, which improves the performance of decoding in presence of noise. After a few iterations, the decoded bits converge to the true transmitted message.

The heterogeneous structure given in Figure 1 consists of two types of wireless nodes: low capacity nodes, and super-nodes. The low capacity nodes are passive units that are designed using wireless SAW technology. Super-nodes interrogate these passive devices and collect their measurements of the environmental parameters such as temperature and pressure. The super-nodes will then transmit the collected data to a gateway for further processing.

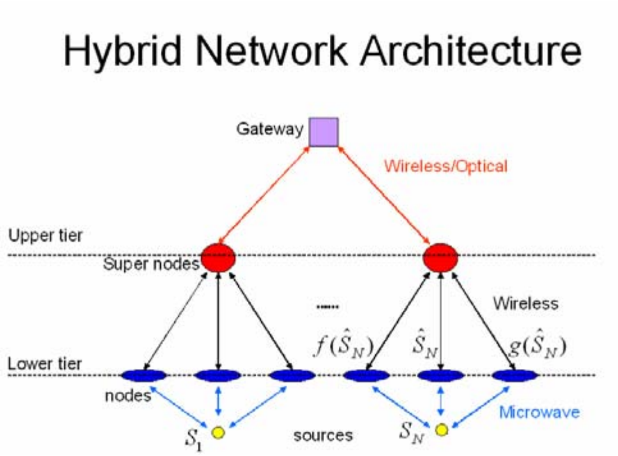



**Figure -1**

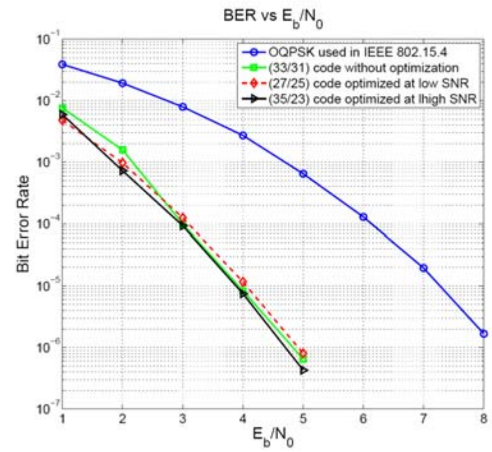
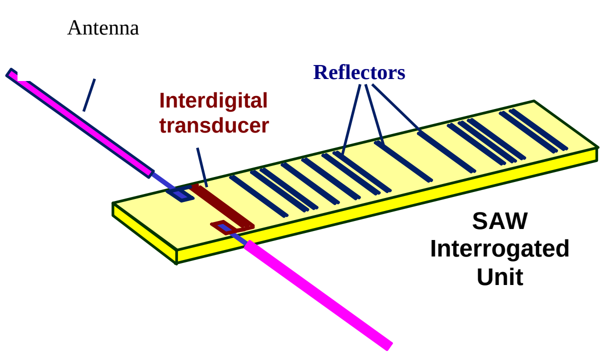


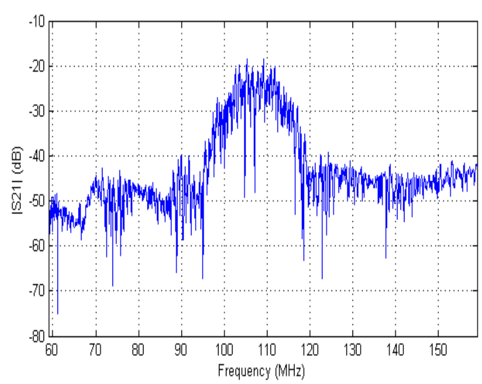

**Figure -2**

## 3. Lower Tier and Interrogation Units

The designed system at the University of Maine uses wireless and passive data acquisition points based on direct sequence spread spectrum using wireless surface acoustic wave matched filters. The proposed technology provides wireless passive operation with high reliability. The digital wireless communication system was implemented into Field Programmable Gate Arrays (FPGA) to provide a flexible design at low cost. Simulation results for an active network (a modified 802.15.4 PHY) are presented in Figure 2. A new channel code is added to the PHY and optimized for both low and high SNR regions, which provides 2-3dB gain.

A representative SAW wireless tag is depicted in Figure 3. The technology allows for passive wireless interrogation links, with the added advantage of tagging, i.e., addressing multiple sensors or interrogated units at the same time. In this work, spread spectrum coding is added to the device technology to improve the communication system robustness to noise and interference. Figure 4 shows the spectral response of one of our wireless SAW matched filter tags. The spectrum represents a 31-bit pseudo random code.




**Wireless SAW interrogated Unit**

**Response of the Matched Filter SAW Tag**