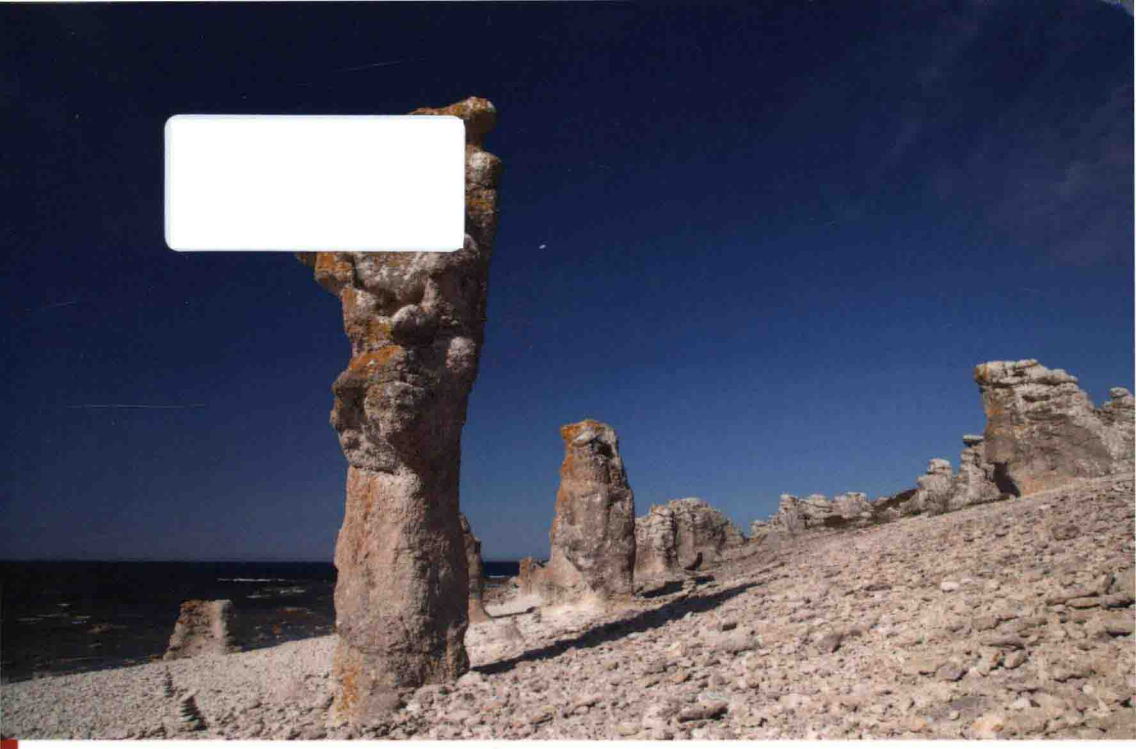

Valentina Marioli

Towards Virtual Synchrony in Wireless Sensor Networks

Design, implementation and evaluation of a broadcast protocol using Virtual Synchrony in Wireless Sensor Networks

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List of abbreviations

ACK	Acknowledgement
AP	Access Point
BS	Base Station
CH	Cluster Head
CSMA/CA	Carrier Sense Multiple Access/Collision Avoidance
FEC	Forward error correction
FIFO	First In First Out
GSM	Group Membership Service
MAC	Medium Access Control
NIC	Network Interface Card
OMNeT++	Objective Modular Network Testbed in C++
OVS	Optimistic Virtual Synchrony
VS	Virtual Synchrony
WSN	Wireless Sensor Network

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To them I dedicate this thesis.

Abstract

This thesis presents the design, implementation and evaluation of a broadcast protocol using Virtual Synchrony paradigm in order to guarantee data consistency on sensors in a Wireless Sensor Network.

Virtual Synchrony (VS) is a technology, created by Birman and Joseph in the early 1980's to support distributed applications that guarantees a strong notion of consistency. A virtually synchronous environment allows processes to be structured into process groups, and makes events like broadcasts to the group as an entity, group membership changes, and even migration of an activity from one place to another appear to occur instantaneously – in other words, synchronously.

The thesis can be divided into two parts: the first contains an introduction to the main concepts: Wireless Sensor Networks (WSN)s, fault tolerance and VS. Since, WSNs are a collection of nodes organized into a distributed system, we can see each sensor as a replica, so we propose a broadcast protocol to guarantee consistency among sensors and explain how using VS we can improve fault tolerance. In the second part, we describe the design of a simulation of our protocol and evaluate the results. The simulation is based on the OMNeT++, a C++-based open simulation framework. We evaluate the proposal protocol by comparing

the results of different network topologies and a generic broadcast protocol without guarantees.

The results obtained with the simulation developed are satisfactory because the tests show that using VS paradigm in WSNs we increase the number of messages successfully delivered. However, the tests show that a protocol designed to be fault tolerant presents, even in the absence of failures, worse performance than one which does not tolerate failures.

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1. Illustration Index

Chapter 1

Introduction

Virtual synchrony is a convenient paradigm for developing distributed applications in asynchronous systems in which processes may crash, messages may get lost, and the communication network may get partitioned, since it simulates a reliable delivery fail-stop model to the application. Virtual synchrony creates an illusion to the application that it runs in an environment in which crashed processes are always detected, and if a certain process is suspected of being crashed, then this process has really crashed. This is done by presenting processes with views, which consists of the set of currently reachable and operational processes. The system then guarantees that between every two consecutive views v1 and v2, no message that was sent from a process not in v1 can be delivered and that all processes that appear in both v1 and v2 have to see the same set of messages. In particular, the use of virtually synchronous communication systems greatly simplifies the task of developing replicated services: It is possible to send a message to the entire set of processes, and the system would ensure that all live replicas will receive a copy of the message. Moreover, if one of the replicas would become faulty, other replicas

will learn about it by receiving a new view which does not include the crashed replica, and one of the live replicas would take over the job of the crashed replica.

Wireless Sensor Networks (WSN)s are a collection of nodes organized into a distributed systems. Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion.

The feasible applications of WSN can be classified into environmental, military, health, and home applications, etc. Some of these applications should send the sensed data in real-time and be recovered even if the unexpected failures have been occurred. Otherwise, we may suffer from severe damage on economic or environment. Here, we call these applications as "mission-critical" applications over WSN. The typical examples of these applications are fire alarm, monitoring of toxic area, habitat monitoring, radiation leak in nuclear power plant, and surveillance reconnaissance, etc. In these applications, reliable and timely delivery of sensory data plays a crucial role in the success of the mission. Factors such as hardware defects, energy depletion and considerations about the environment where the network is deployed affect their reliability. The goal is to provide reliable storage over an unreliable network. Replication can be used to provide data availability. In the context of sensor networks,

the biggest challenge is the placement and management of replicas.

Properties of virtual synchrony make it especially beneficial for "mission-critical" applications to maintain consistency of replicas. Unfortunately, existing systems that support a virtually synchronous communication paradigm cannot be directly applied to wireless sensor networks and a new solution is necessary. The main reason is that the set of assumptions has changed dramatically. Existing VS research has assumed that the systems are wired, have unlimited power, have a fixed set of resources, treat each node in the system as very important and are location independent. In contrast, for wireless sensor networks, the systems are wireless, have scarce power, have dynamically changing sets of resources, aggregate behavior is important and location is critical.

1.1 Contributions of This Thesis

This thesis takes the first steps towards the use of Virtual Synchrony in Wireless Sensor Networks. In order to guarantee replica set reliability, we present the design, implementation and evaluation of a broadcast protocol using Virtual Synchrony paradigm.

We image to have a two-tiered wireless sensor network organized as a number of clusters where each sensor node belongs to only one cluster. Some nodes are treated as cluster heads (CH) and have additional responsibilities (e.g. data gathering, data aggregation and routing) compared to the remaining nodes. All nodes in the network act as sensor nodes collecting information from the