Architecture for Wireless Sensor and Actor Networks Control and Data Acquisition

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Abstract—Wireless Sensor and Actor Networks (WSANs) have received increased attention from the research community in the recent years. This is mainly because as an extension to Wireless Sensor Networks(WSN), they have the ability to actively participate in the environment trough the actors. However, this introduces new challenges as to how to transfer commands between nodes, actors and central station who may be from different manufacturers and use different communication protocols. Another important aspect is the ability of the WSAN to present the data to the interested party or to receive the command from the operator, and do this with in the simplest and most user friendly way as possible. In this paper we propose architecture for interconnection between different layers of WSANs and the central stations that would allow building a simple interface that would ease the operation with WSANs in view of Control and Data Acquisition.

Keywords-component; Wireless Sensor and Actor Networks; Remote Data Acquisition;Control Interface

I. Introduction

WSAN can be consisted of multiple sensor nodes that allow acquisition of data from the environment and multiple actors (robots, actuators) that execute actions and influence the environment. These actions can be programmed by an operator or autonomously, based on the sensor data that is acquired. Sensors and Actors in WSAN create an ad hoc network and they communicate with each-other on demand. The actors and the sensors can be able to communicate with a central access point that could be used as data sink and as a point from which all the commands for the actors would be sent. WSAN architecture can contain multiple such points. In WSAN there are many challenges that are considered and described in [1], where also WSAN are divided in two groups: WSAN with automated, and WSAN with semi- automated architecture. In the first group the sensors send their data to the actors and the actors act as sinks for the sensor network. In the latter architecture, the data is sent to a single sink and actors receive all the data they need from that sink.

WSANs are becoming more and more popular with the research community due to their capabilities to eliminate the human factor in the interaction with the environment and to automate the response in case of emergencies. Multiple challenges are considered and solutions to some of them are suggested, however, there are still many challenges that need to be addressed and wait the attention from the community [2,3,4].

WSANs allow employment of different types of sensors that could be made available in the sensor nodes of WSN. Furthermore, WSANs upgrade WSNs' capabilities due to the ability to employ sensors that have higher energy consumption which is usually an obstacle for their integration into WSNs. A mobile robot that acts as an actor could easily use its camera to obtain visual data from the environment. This data can be also available to the other WSAN nodes and could be used for more advanced functionalities. This increases the sensing capabilities of WSANs and makes them more adequate for many applications such as perimeter guarding, intrusion detection and prevention, forest fire prevention, timely response to environmental changes etc.

In this paper we consider an architecture design for easier implementation of control mechanisms for WSANs and for data acquisition from WSANs. In Chapter II we describe the proposed system architecture for our design and describe the possible use-case scenarios. In the third chapter we give a brief description of the current implementation and challenges and of the expected results from the implemented architecture.

II. System Architecture

The basic structure of a semi-automated architecture could be given on Figure 1.

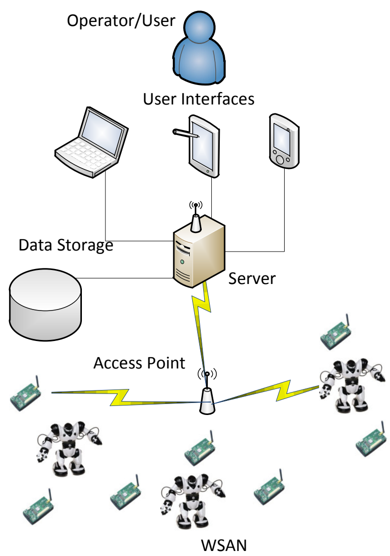

Figure 1. WSAN Semi-Automated Architecture

On Figure 1 is illustrated that the operator or the user could have wide variety of interface tools that communicate with a dedicated machine, in our case the server that acquires all the data from the sensors and the actors and is able to send commands to the sensors and the actors. Since WSANs integrate a variety of technologies, they have to address multiple challenges on all levels of control, sensing and communication, such as: localization and mapping, communication and routing, path planning, target tracking, standardization of hardware services/interfaces, security etc. Every WSAN based system must account for many of these problems. In the proposed approach, the main focus is on the usability of different hardware products with minimal hardware intervention and the ultimate goal is a plug and play capability of the WSAN, where a new sensor node or actor can be introduced to the WSAN and it can be reconfigured with as little effort as possible. This kind of architecture is given in [6] where the proposed architecture is implemented and tested and the results of the responsiveness are given. In [5] a modified architecture is given that allows different pathways of the commands and the sensor data acquisition. The sensors and the actors may communicate from different interfaces with the server and as described in [5], may also receive commands from another communication interface (a mobile phone SMS message in this case). This opens a wide perspective in the development of architecture for WSAN. The data sink, the sensor nodes and the actors could be manufactured from different vendors, use different communication protocols, but to be able to communicate with a single server. For the implementation of the system proposed in [5], MicaZ sensor nodes [7], and the Robosapiens robot [8], which is modified to use mobile device as driver, are used.

In this paper we propose an extension to the semi-automated architecture that would allow integration of single or multiple WSAN systems under one interface. This would enable ease of access to the data that is collected by the sensors in WSAN, and also would greatly simplify the task delegation to the actor systems. A further extension of this architecture could even allow online reprogramming of the sensor/actor nodes.

The proposed system, as shown in Figure 2, is consisted of four main modules:

- The User Interface - that is used for display of the acquired data.
- The Middleware module – That orchestrates the interconnection of different parts of the system and acts as sink for the WSAN.
- The Communication Interface – Consisted of different units that allow connection of hardware from different manufacturers
- The WSAN - A Network of Actors and Sensors that communicate with each other and with the Middleware.

Further in this section each of these parts will be explained in more detail.

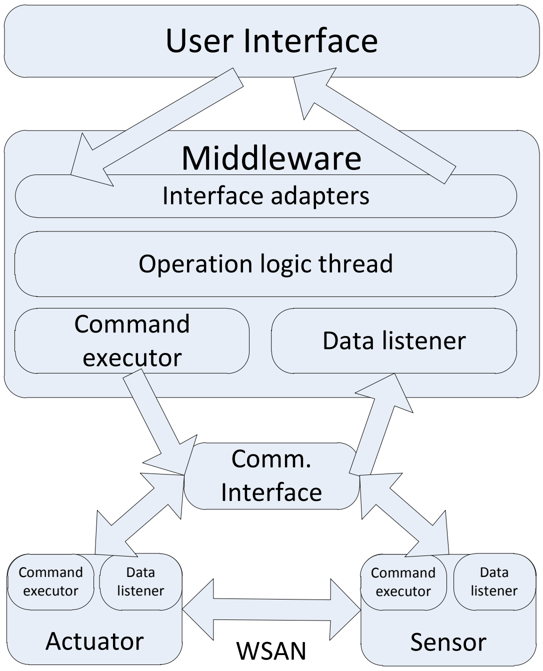

Figure 2. System architecture

A. *The User Interface*

The user interface is the part of the architecture that is in direct contact with users or operators of the WSAN. The user interface can vary from simple desktop application, to web application and mobile application. Further, the user interface can be developed in such way that would allow reprogramming of the other parts of the architecture.

B. *The Middleware*

The middleware is the most complicated and most important module of this architecture. The middleware consists of four main threads.

The first thread is responsible for communication with the user interface. It is shown on Figure 2 as the “Interface adapters” module. This thread has to be robust in such way that would allow multiple different types of user interfaces to connect to the middleware and allow authentication of users. This part is the entry point to the middleware from the operator/user side. It registers its services, so that they are available to the user and calls the service implementations on the lower parts of the middleware.

The second thread is the main loop of the middleware part. This thread contains the main logic of the middleware and communicates with the other threads. This thread is shown on the figure as Operation logic thread.

The third and the forth thread are the Command executor and the Data listener as shown on Figure 2. The Command executor and the Data listener work as a proxy between the middleware and the communication modules. The Command executor translates the command given from the operator and sends it to the corresponding actor or sensor. The Command executor must establish communication with the corresponding node using the communications interface before sending the command. The Data listener, as the name suggests, waits for new data from the sensor nodes or from the actor nodes and then sends the data to the upper layers. The Data listener is also able to process the data using different kinds of filters in order to give the user only the data he needs, thus optimizing the data flow through the system.

C. *The Communications Interface*

It allows multiple communication links to be able to communicate with the middleware. This part is consisted of modules for each communication interface that is available to the middleware. The Communications Interface is able to register nodes that enter the WSAN and to register nodes that exit the WSAN. The Communications Interface should be robust enough to allow different types of sensors and actors that use different communication protocols to be able to communicate with the WSAN.

D. *The WSAN*

This is the main module of the architecture as the whole sense of this architecture is connected with it. The WSAN is consisted of nodes that can be actors or sensors, both of which should be able to communicate with the Communications interface and trough it with the middleware part. For such scenario, both the actors and the sensor nodes should be able to implement sending and receiving of data. As shown on Figure 2, the sensor and actor nodes should have interfaces similar to the Command executor and Data listener from the middleware, so that they would be able to send and receive data and send or receive commands.

III. EXPECTED RESULTS AND CONCLUSION

The proposed system is currently under implementation. Several of the modules and interfaces in [5], are also being reconfigured in order to become invariant to the technologies that are used. Further we expect to implement a system that would allow multiple WSAN networks to be connected to our middleware that would be able to control, map and obtain data from them and even more, work as a test bed that would be able to monitor and evaluate the effectiveness of WSANs. This system will be tested on the hardware that is available [7 and 8] and in further phases of development it will be tested on nodes from different manufacturers and other types of actors.

We expect this architecture to be able to overcome many of the challenges that exist in the control of the WSANs and in the data acquisition from the WSANs, since this modular architecture would allow efficiency not only in the data exchange but also in the command delegation to the nodes. Also, some other connectivity protocols should be considered (e.g. IP end-to-end connectivity) from which the overall performance of the system could be improved. However, other protocols impose other challenges (e.g. power consumption and efficiency), so the trade backs that have to be also considered and investigated.

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