Modeling of a Humanoid and Multi-agent System

EE382C: Embedded Software Systems

Literature Survey

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Abstract. This survey briefly describes the project to implement an infrastructure for multi-agent systems (MAS) using humanoid robots as agents (HMAS). In order to construct a wireless network that facilitates the design of the infrastructure, this paper reviews some current technologies and researches in wireless networks. The research focused on the following layers of the International Standards Organization (ISO) layered model - Open Systems Interconnect (OSI). There are different modulation proposals of Ultra-wide Band (UWB) technology at the physical layer (PHY). The media access control (MAC) protocols are discussed in their facilities of low power dissipation, mobility management, and assurance of the Quality of Service (QoS). The survey also studies different network designs and evaluates their applicability in HMAS project. The choices for the network designs include cellular network, ad hoc network, and sensor network.

I. Introduction

MAS is a sub-field of AI that aims to provide both the principles for construction of complex systems involving multiple agents and the mechanisms for coordination of independent agents' behaviors [16]. Generally, an agent is capable of detecting the environment, deciding actions based on the detection, and executing the actions.

This projects aims to develop a flexible infrastructure for realizing multi-agent systems for educational and research purposes. The infrastructure has a base-station to handle heavy duty computations and a number of humanoids to act as agents. Recently, studies in multi-agent systems have explored areas such as robot soccer (RoboCup) and mobile sensor networks. Realization of these MAS systems through HMAS will be valuable to these researchers.

The following sections will describe some prior works in developing a wireless network from the physical layer to the network layer of the OSI model. Section II introduces the specification of the network designs in HMAS and the challenges of the project. Section III, IV, and V introduce the recent researches in UWB, different MAC protocols, and different network designs for this application. Section VI briefly describes the future implementation of this project and summarizes this survey.

II. Humanoid Multi-Agent Systems

The infrastructure needs a high-quality wireless communication network that is mobile, cheap, and fast. UWB has become a very good candidate for this purpose. However, the implementation faces a few challenges. First of all, transceivers of UWB are very expensive because the lack of mass production. Secondly, the IEEE 802.15.3a protocol to be used with UWB is not yet standardized [7].

Moreover, simulation tools with UWB are not common. Further, further researches reviewed that there are no current protocol designs at the MAC layer that are directly applicable to our project. The proposed solutions to these problems would be addressed in Section VI.

III. Physical Layer

A. History of UWB

The Federal Communications Commission (FCC) defined a UWB device to be "any device where the fractional bandwidth is greater than 0.25 or occupies 1.5 GHz or more of the spectrum" [7]. FCC also allocated 7.5GHz of spectrum for unlicensed use of UWB devices in the 3.1 to 10.6 GHz frequency band. Although its applications are new to many people, the concept originated from the 19th century. In 1978, C. L. Bennett discussed the application of short-pulse radio signals in time-domain electromagnetism [4].

IEEE 802.15.3a Task Group (TG3) adopted UWB as the physical layer of the Wireless Personal Area Network (WPAN) [8]. Different modulations are proposed for UWB over the last couple of years [14], [15], and [2]. After a long time of debating, the IEEE 802.15.3a task group (TG3) approved a dual-PHY approach with a single-band, direct-sequence-CDMA proposed by Xtremespectrum and Motorola, and multi-band-OFDM proposed by the Texas Instruments/Intel-led Multiband-OFDM Alliance (MBOA) [16].

B. Why UWB?

We select UWB to be the physical layer of our network is because it fulfills our design constraints. UWB has a large frequency spectrum and large bandwidth. It is able to transmit a large amount of data through short ranges within 10 meters. The way that impulse trains of UWB signal propagates allows simple transceiver design and hence the hardware cost is [14]. The only drawback for UWB is its performance decline over incremental transmission range.

IV. Media Access Control

A. Definition

MAC is a sub-layer in Data Link (DL) layer of the OSI model. It defines the protocol for packet transmission and it acts as a interface between the network and the physical layer. [11] studies different MAC protocols and evaluates their performance on channel acquisition time using UWB as the physical layer. The following sub-section presents a literature in the MAC level of networking for sensor network. Sensor network will be discussed in Section V.

B. Protocols for Self-Organization of a Wireless Sensor Network

Sohrabi et al presents a set of algorithms to instrument a sensor network that had a strict constraint on low power consumption [12]. They assumed that most of the nodes in the network were stationary once after deployment, and that the number of mobile nodes was small.

First, they described how they combined the neighbor discovery and channel assignment phases, which were separated phases in many algorithms, to construct a stationary network. In their algorithm, each node would randomly pick a frequency to avoid collision in communication. They adopted the time-division multiple access (TDMA) approach that required each node to reserve time slots for neighbors. These slots are brought up periodically during which the node could communicate with one of its neighbors. These network propagated the slot allocation schedules until all the nodes were connected to enable multihop communications.

Secondly, they presented the Eavesdrop-And-Register (EAR) algorithm to address the mobile node issues. They again assumed that the stationary neighbors of the mobile agents would broadcast invitation messages to all the surrounding nodes. When the mobile node received an invitation, it decides whether to disconnect from a node or to connect to a node based on geographic, energy, or transmission quality. Both the mobile nodes and the stationary nodes kept registries of the connected mobile nodes.

Finally, the authors presented a Sequential Assignment Routing (SAR) algorithm. To detect the network topology, the nodes one-hop away from the sink (destination) would serve as the roots of multiple trees and expand its coverage until most high quality nodes became the members of the trees. The paths carried information about its energy resources and some QoS metrics. SAR kept tracks of the information periodically to ensure good performance and good routes.

V. From Network To Applications

A. Review of Network Designs

The interesting applications of UWB is in mobile networks that cover a large area. There are three kinds of network design that match the requirement of the infrastructure and the constraints posed by its applications:

1. Cellular network: different cells cover the entire area. There is a stationary base-station in each cell to route the communication between the nodes in the cell and the server. Cellular networks are widely used in mobile phone service. [21] describes a model of cellular network and provides information on how phone companies address the issue of pass-off disconnection when mobile nodes move from one cell to another.

2. Ad hoc network (packet radio): nodes act as routers. Instead of communicating with a base-station, each endpoint would communicate with a switch, and the switches will route the data to and from the server. There are currently more than 70 protocols for ad hoc networks. Some of them are described in details by [24]. [10] evaluated a few common routing protocols used in wireless ad hoc network. [18] and [5] investigated into routing protocols that address the QoS issue. [8] presented an algorithm to dynamically predict the movement of a node to avoid the lost of network information when switching its router.
3. Sensor network: nodes are generally stationary after deployment. Connections are assumed to be moderately stationary with a reasonable amount of mobility. The applications of sensor network is, interestingly, connected with cooperative robotics, in which robots share the common goals and benefits to solve a hard problem. It is also used in study of sociology and animal behavior[23]. Researches on sensor networks have been focused on energy conservation in [20], [6], [1], and data gathering [22]. Also, since the behavior of sensor network is different from the ad hoc network, they would be fit to different MAC protocols.

The design at the network layer generally addresses three kinds of problems: topology control, data communication, and service access problem. The routing mechanism is very important to maintain the network connectivity. The design of the routing mechanism is affected by both the choice of the MAC protocol and higher-level application requirements.

B. Sensor Information Networking Architecture and Applications (SINA)

Shen et al described a data-centric SINA to facilitate “querying, monitoring, and task of sensor networks” [3]. SINA was a middleware between the application layer and the network layer. Its design, however, posed constraints on the routing mechanism used at the network layer.

The paper first describes the three functional components of the architecture. In order for the nodes to respond faster, they were grouped in hierarchical clusters with cluster heads. A cluster head was responsible for tracking the information collected by its neighbors and reporting to a query about members in its cluster. Then the network did not need to wait for response from all the nodes. The second component was attribute-based naming scheme in which the sensor nodes were named by their sensor attribute-values. The network could direct queries to nodes whose naming matches the content of the queries. The last component was the location awareness, which achieved network efficiency by using a tracker, such as a Global Positioning System (GPS). The sensor nodes are then geographically sensible to the queries.

The more interesting discussion in this paper is the mechanisms to gather sensor information for information fusion. The first one is sampling operations in which samples are selectively collected from sensor nodes whose participation is decided by a “response probability”. The second mechanism is the self-orchestrated operation. The sensors that are more hops away from the front-end, which posts the query, is delayed for transmission to statistically avoid response collision. The last one is diffused computation operation in which the some sensor nodes are capable of integrate the information received from the neighbors and the aggregated information is passed to another sensor, until it reaches the front-end. This way the front-end is free from analyzing all the data at once and the network traffic is reduced. The only drawback for this mechanism is that the long latency to get the answer for a query.

C. Cross-Layering in Mobile Ad Hoc Network Design

The previous literature showed that higher-level design could affect the lower level protocol design. The naming scheme and the location awareness affected the election of a router in the cluster. Therefore, the efficiencies at different layers were interrelated. Conti et al proposed a cross-layered design in the complete protocol stack [13]. Previous works only focused on specific applications that involved only part of the stack. The authors proposed a Mobile Metropolitan Ad Hoc Network (MobileMan).

The core idea in MobileMan was a jointly accessible component called Network Status. All layers in the protocol stack or OSI model, from the physical layer to the application layer, could access this repository and gather information about the other layers. This optimized the performance in "stackwide features" such as energy management, security, and cooperation. However, the protocol design and implementation of different stack layers were still separated to allow modification of the independent layers. Currently MobileMan facilitated IEEE 802.11 MAC with redesigned protocols. We should expect more literatures from the MobileMan project members in the near future.

VI. Summary And Implementation

This survey presents the development in UWB, MAC protocol, and network designs from the 1960s to 2004. It summarizes some major developments in different areas and evaluates their applicability in HMAS. The focus of this project is on the network design of the HMAS. Possible solutions include cellular network, ad hoc network, and sensor network. The information reviewed by this survey revealed the potential of UWB in network development, and that it is a strong candidate for the physical layer of HMAS network. Moreover, HMAS can switch network topology to take advantages of the different network designs. Future work involves the design of such a network system and the simulation of the network using Network Simulator 2 (ns2) or OpNet.

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