

Auto configuration and management mechanism for the robotics self extensible WiFi network

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Abstract: When a disaster happens in an area where people live in and there are victims at there, a rescue team is organized and sent to save the victims. Traditionally, the rescue parties run a risk of their own lives to save the victims. We believe that recent progress of robotics technologies and networking technologies can help the situation. We propose the idea of the autonomous network construction system and the remote investigation system of the disaster area by robots. We defined such a network as *Robohoc* network in our previous paper [1]. In this paper, we propose one of the design ideas that suits the Robohoc network requirements defined in [1].

Keywords: Rescue robots, Self-organized network, Ad-hoc network, wireless mesh network

1. BACKGROUND

The demand of feasible rescue robots is increasing recently. As there are some prototype robots those are designed for rescue purpose, such robots have problems in their operation model in disaster areas. Current robots are mainly controlled by a wired link or by a short range wireless link. Using these links requires the robots operator to step into the disaster area with their robots. This is not recommended way because such a stricken area is usually in danger, especially just after the disaster. We have to be careful not to cause secondary disasters when we perform rescue activities. Providing a safer operation environment for robots operators is mandatory as one of the core requirements to make a feasible rescue robots solution system. In this paper, we propose one of the network designs for such a rescue activity.

2. ROBOHOC NETWORK

The *Robohoc network* is a new term defined in our previous paper [1]. In the paper, we proposed a new style of a rescue network that can be dynamically extended and autonomously maintained by robots, called Robohoc network.

The Robohoc network is constructed as follows. In the beginning of the rescue activity, we have no network for robots control. Figure 1 shows the initial status. The operator is located at the initial position (*Point Zero*) and has one wireless access point (*Robohoc Router, RHR*) besides the operator. In this stage, the robot can move only the area that is covered by the RHR1.

The robot will carry RHRs and puts them on the path between the Point Zero and its final target point. Figure 2 shows the final image when the robot reaches the target

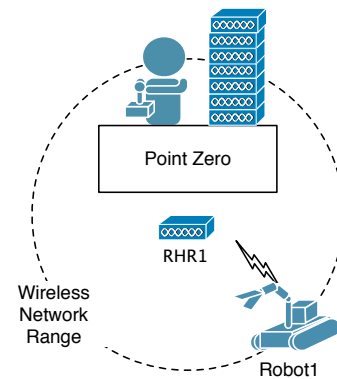


Fig. 1 The initial Robohoc network topology.

area.

We thought that this type of dynamic expanded network by robots would be mandatory when providing a control and investigation network infrastructure to rescue robots operators. Since our target application is rescue activity, and the operation field is a disaster area, we defined requirements those are necessary to realize such a network in the extreme area. Table 1 shows the requirements we concluded in the paper [1].

3. BASE SYSTEM REQUIREMENTS

We summarized the requirements for the rescue robots network in section 2. however, some of them can be optional requirements depending on the activity scenarios. We defined that the following 4 requirements are mandatory requirements as a base system. Without these requirements, the network cannot be act as a Robohoc network.

1. **Communication distance:** The diameter of the network must be a few hundreds meters to 1 kilometer, to cover the search areas and to keep operators away from the disaster area.

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<i>Required property</i>	<i>Description</i>
RHR (Robohoc Router) distribution	RHRs and robots cannot be located uniformly. The Robohoc network must support the non-flat node distribution.
Communication distance	The distance between teleoperators and robots is from a few hundreds meters to about 1 kilometer.
Network partitioning	The Robohoc network may be partitioned while constructing the network or operating rescue activities. The network must have a property to recover from partitioning.
Real-time robots control	For real-time robots control, the network latency has to be less than 400ms. Robots can be controlled even the latency is more than 400ms using however, in that case, the latency has to be predictable and stable.
Type of service support	The Robohoc network must be able to provide different traffic properties for different contents, for example, the real-time delivery for the robots control and the wider bandwidth for the live streaming.
Topology information sharing and storing	When recovering from partitioning, teleoperators, RHRs and robots have to know the topology of the network to find the failure point. The topology information must be shared and stored in every node.
Bootstrap and auto-configuration	The network construction and rescue activities must be started as soon as possible. Every node must start with minimum manual configuration and must have an auto-configuration property.
Hop counts	The number of RHRs in a Robohoc network may be more than 100. The average hop count in this case would be more than 20. To support a wider area, the number of hops and average hop count will increase.
Layer 2 information utilization	The Robohoc network uses a wireless communication media to create the network. Each RHR has to monitor the link quality of their connections and utilize the information for better performance.
Fault Tolerance	The Robohoc network must not have a single point of failure. The network must be able to recover from partitioning either by the human intervention or by autonomous recovery actions of robots.

Table 1 The summary of the requirements for the Robohoc network.

2. **Bootstrap and auto-configuration:** Since we need to begin rescue activity quickly, we have to configure all equipments before visiting the disaster area.
3. **Layer 2 information utilization:** The wireless quality highly depends on the surrounding environment, we need to utilize layer 2 information to make a stable network.
4. **Fault tolerance:** In case of accidents of components of the network, we need to design the network fault tolerant.

In the next section, we detail the design of the base system.

4. BASE SYSTEM DESIGN

In this section, we describe the overview of our system and its components, explaining how these components contribute the requirements we defined in section 3.

Figure 3 depicts the entire system overview. The network is constructed with four different types of nodes. The first type is a wireless mesh router (WMR) node, that is used as a core component of the backbone network. We adopt IEEE802.11a and IEEE802.11g link layer protocols to connect each WMRs. Since these link layer protocols can provide long transmission range (almost up to a hundred meter, depending on the environment), we can achieve requirement 1. Also, these protocols can be adapted to various different wireless environment by con-

figuring its link communication property with the support of link layer information (requirement 3). For example, if the surrounding environment has noise that interferes our wireless communication, we can use more robust modulation algorithm instead of getting higher throughput. The WMR will scan its surrounding environment and determines what kind of wireless channel can be available and what type of modulation algorithm should be used. The neighbouring WMRs will communicate each other and determine its communication property, and extend the size of the network autonomously.

The second and third type of nodes are a location mapper and a mobile router respectively. A mobile router is a moving router, that is intended to be equipped inside the rescue robot. By using mobile communication technology, we can reach each robot by specifying its fixed identifier (for example, by an IP address). The mobility function will hide the movement of each robot and provides us a transparent access method to the robot. This contributes bootstrapping and auto-configuration requirement (requirement 2). Since each robot has a fixed identifier for communication, we don't need to decide it dynamically. These identifiers can be configured in advance.

The fourth type is a normal node, that will be equipped in robots. For example, camera and sensor nodes of a robot will be this type of node. Thanks to the mobility

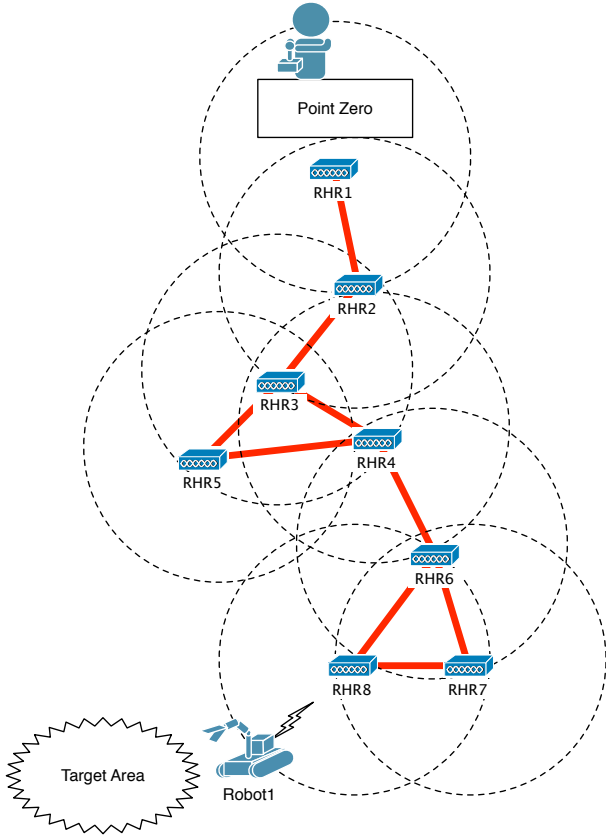


Fig. 2 The fully expanded Robohoc network topology.

function, these nodes can act as if they are located in a fixed network, and we can use these devices without any modification.

The backbone network uses routing protocols specified for the Internet operation. Since the Internet is designed as a autonomous system in nature, the protocols used in the environment is designed as distributed protocols. By using the distributed protocols for backbone maintenance, and by configuring redundant paths (for examples, creating redundant links and putting multiple location mappers), we will achieve requirement 4.

5. CONSIDERATION

In this section we discuss how we achieve each requirement in detail and justify our proposed Robohoc network system.

5.1 Communication Distance

To provide wider rescue network with lower number of router nodes, we need to maximize communication distance between wireless routers. As explained in the previous section, we adopt IEEE802.11a and IEEE802.11g protocols to connect two wireless routers. We will use both protocols at the same time to construct the backbone network to get enhanced throughput. To get better cost performance, we are building the system using easily available devices (in other words, we do not plan to use specially crafted devices). However, from our past experiment, if we use IEEE802.11a/g devices used for

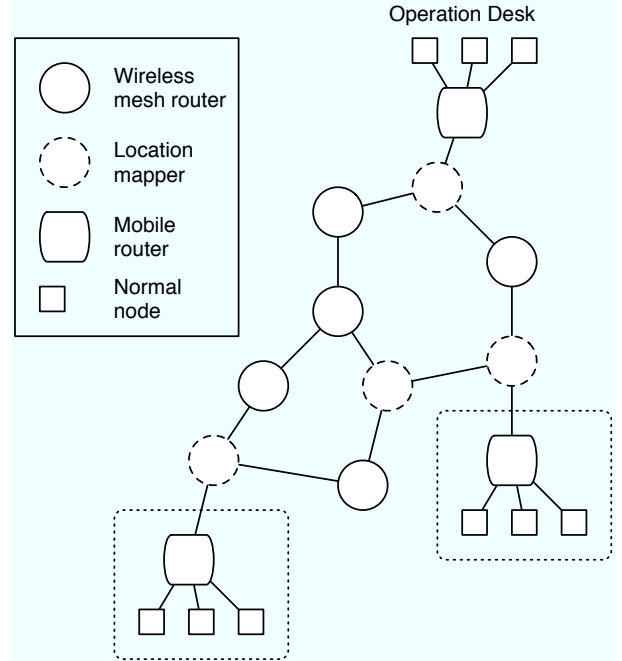


Fig. 3 The base Robohoc network system

consumer computers, the throughput of a multihop wireless link is lower than its theoretical expectation. Figure 4 shows the result of experiment. When the number of hop count was 1, we could get almost ideal throughput between two terminal nodes. However, each time we added an intermediate hop, the throughput decreased. With 6 hops, we could only get one-fourth performance of the 1 hop case.

By investigating the problem, we later found the problem was caused by wireless interference. Although we configured all the wireless links constructing the multihop link to use different IEEE802.11a channels, that kind of configuration didn't help the problem. As we implemented multiple wireless network cards side by side in one box, even though we use different channels, the interference occurred. The problem was in the accuracy of the physical band pass filter. As it is difficult to get wireless card that provides more accurate band pass filter function because of cost reason, we need to use different approach. In paper [2], the authors proposed using two different bands to create a mesh network. We utilize the same approach for better performance and longer range of the multihop wireless link path. Although [2] mentions only a static wireless mesh network case, we think the similar approach can be possible for the Robohoc network.

5.2 Bootstrap and Auto-configuration

In the rescue activity, we need to minimize the preparation time for operation, and have to start the activity as soon as possible once a disaster happens. We also need to avoid manual network configuration procedures of nodes during operation, since such procedures are not main purpose of the rescue activity. In Robohoc network, the network is dynamically extended. There are exist-

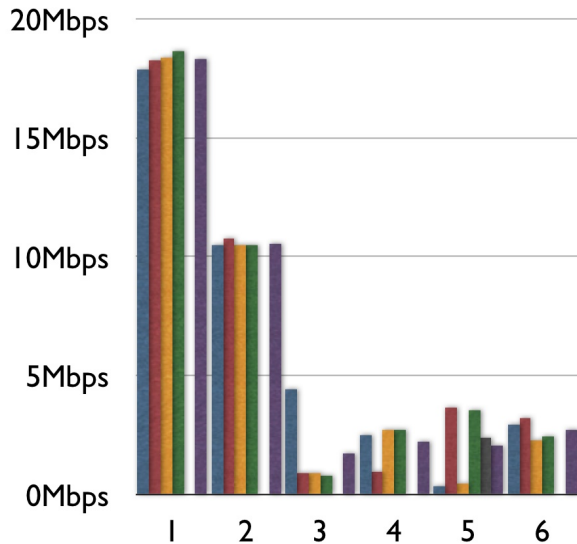


Fig. 4 Throughput reduction in a multihop wireless link constructed by IEEE802.11a. The topology was a liner topology. All the wireless links between two wireless routers used different channels of IEEE802.11a, so that there would be no interference (in theory).

ing papers for ad-hoc routing management protocols and various optimization approaches for mobile ad-hoc network environment, however, there is no discussion on how to dynamically negotiate wireless bands and channels based on the existing topology and surrounding environment. In the existing papers, most of these parameters are known parameters and pre-configured. In a real environment, however, we need to set up these parameters on the fly appropriately. To avoid configuration procedure of each RHR when placing, we are investigating dynamic configuration mechanism of connection parameters of RHRs [3].

For the robot node which moves in the Robohoc network, we propose a mobility protocol in this base system proposal to reduce pre-configuration overhead and routing overhead during operation. Each mobile router node has pre-assigned fixed network prefix as its identifier. These identifier does not change throughout the rescue operation. Such a layer 3 mobility technology is already proposed in IETF [4], however, [4] assumes a reliable infrastructure network which is not the case in an ad-hoc networking environment. We are investigating distributed approach for the mapping mechanism to bind the node identifier and its location information.

5.3 Layer 2 Information Utilization

As we may see uncontrolled or broken wireless access network or may see radio wave interference sent from broken infrastructure, we need to tune wireless communication parameters to achieve best performance in such environment. For example, the IEEE802.11a system defines multiple transmission rates (6, 9, 12, 18, 24, 36, 48,

54Mbps) based on the minimum signal input level. When placing RHRs in a disaster area, we need to measure the surrounding environment and configure proper rate using a robot. We also need to consider to fix the rate or use the dynamic rate adaptation mechanism, depending on the stability of the environment. Choosing the band of wireless link (for example, IEEE802.11a and IEEE802.11g) is also important to get better performance. Many existing proposals discuss methods to measure the surrounding environment and calculate optimized parameters for static environment, however, discussion for the extending network in a dynamically changing environment is not enough. We are investigating the way to calculate the parameters in such an environment.

5.4 Fault Tolerance

In an ad-hoc environment, the fault tolerance of the system is important. In our proposed base system, we are seeking a dynamic network construction and maintenance mechanism for the Robohoc network as discussed in section 5.2 For the mobility function part of mobile routers used by robots, we propose multiple mobility management servers operation as shown in Figure 3. The existing mobility management mechanism also has a redundant mechanism for higher service availability [5], however, similar to its base mobility protocol [4], the proposed mechanism is designed for a well-managed infrastructure and cannot be applied to the Robohoc case.

6. CONCLUSION

The demand for rescue robots operation is growing to achieve safer rescue operation and broaden the exploring area of the disaster region. The combination of robotics technology and wireless multihop technology is one of the solution for the requirement. In this paper, we focused on 4 requirements (communication distance, bootstrap and auto-configuration, layer 2 information utilization and fault tolerance) and proposed a simple network model. The proposed model can be considered as a minimum Robohoc network. We are now designing the implementation detail based on the proposal to embody the network.

7. RELATED WORKS

[6] also considered ad-hoc networks as the backbone networks. While we are constructing mesh networks from the beginning, they were working on ad-hoc networks already constructed. Since it is difficult to prepare networks for all places where can be damaged by disaster, how fast and reliably a network can be constructed is important.

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