User Policy Based Transmission Control Method in Cognitive Wireless Network

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Abstract. Remarkable wireless networks technology developments have made us to expect the realization of new applications like the advanced traffic system, the disaster prevention system, and the adhoc network system. However the resources of wireless bandwidths are not enough to use for such new applications because it is not efficient usage. Therefore, it is necessary to develop with new efficient wireless transmission methods like cognitive wireless network. In this paper, the transmission control methods in cognitive wireless network considering with cross layers including user policies are discussed. First, at the observation stage, the physical data such as user policy, electric field strength, bit error rate, jitter, latency, packet error rate, and throughput are observed. Then, at the decision stage, AHP (Analytic hierarchy process) is applied for decision making process with those parameters. Finally, the action stage, one of the suitable link is chosen and changed links and networks.

In the simulation, ns2 are used for the computational results to the effectiveness of the suggested transmission methods in cognitive wireless networks.

Keywords: Cognitive Wireless Network; QoS; AHP; AODV.

1 Introduction

Recently the development of wireless networks has been growing in various fields, such as cellar phone, digital TV, and wireless Internet services. Those technologies make us to expect the new application like the advanced traffic system, the disaster prevention system, and so on. However, such a remarkable spread of wireless services cause lack and inefficient usage of radio frequency wireless spectrum, we're in front of a spectrum explosion, that is, one may not have enough wireless resources for new wireless applications. According to FCC reports [6], wireless resources are limited

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and may not be efficient, because wireless device depends on access to the radio frequency (RF) wireless spectrum, and spectrum has been chronically limited ever since transmissions were first regulated in the early 20th century. Therefore, new technologies that use spectrum more efficiently and more cooperatively, unleashed by regulatory reforms, will soon overcome the spectrum shortage.

Cognitive wireless network (CWN) by J. Mitola III [8] from software defined wireless was originally considered to improve spectrum utilization, and generally considered as a technology to identify the opportunities using the “spectrum holes” for telecommunications [1] [2]. In other words, Mitola defined that CWN is an intelligent wireless communication system that is aware of its surrounding environment, and uses the methodology of understanding by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters in real-time, with two primary objectives in mind: highly reliable communication whenever and wherever needed; efficient utilization of the wireless spectrum.

Also, CWN is consisted of the cogitation cycle; observing the environment, orienting itself, creating plans, deciding, and then acting reconfigurations. The cognition cycle is continually responding stimuli from environment, and it makes successful link or path of network.

However, CWN still has some problems to realize like some algorisms, control methods, and technical problems to attain efficient transmission. First of all, it is recently known that CWN needs not only ordinal spectrum management or Physical/Mac layer observation control but also new control method including upper layers. Also, CWN still has technical problems like how to set radio frequency, how to observe its environment, and how to select proper transmission protocol or radio frequency, and so on [3][4][5]. Moreover, CWN needs the QoS algorism to select one of wireless links and network route for each application or user environment.

In this paper, we consider the selecting method of the proper wireless link which each node has several wireless links such as IEEE802.11a/b, and IEEE802.16 (WiMax), and the proper route in which network environment is changing through the time. First, user policy and network parameters are observed at the observation stage. At this stage, we set various policies for video, VoIP, text, disaster applications, and so on. By each policy, the weight parameter is decided for the decision algorism which based on Analytic Hierarchy Process (AHP). Network parameters like throughput, latency, jitter, packet error rate, bit error rate, and electric field strength are continuously measured and also used for the calculation of AHP. Secondly, at the decision stage, the results of AHP for each communication link are compared, and the proper link is selected when the results are changed. Also, if there is no proper wireless links at the observing nodes, proper route is analyzed by extend Ad hoc On-Demand Distance Vector (AODV) algorism. Finally, in the acting stage, the selected link or route is applied for supposed network, and then simulation is carried out for our supposed methods.

In the followings, in section 2, network model and system architecture of our proposal communication method are defined. Section3 deals with the observation stage which is the method of observing network parameters and user policy. Section 4 describes wireless link selection, route selection and decision algorism which based on AHP. Section 5 explains how to change link and route at supposed network. At section 6, the simulation is held for the model by the calculation for the effectiveness of the suggested control method. Finally section 6 derived our conclusion and future works.

2 Network Model

A. Network Configuration
The network configuration of our suggested cognitive wireless network consists of several wireless nodes as shown in Fig. 1.

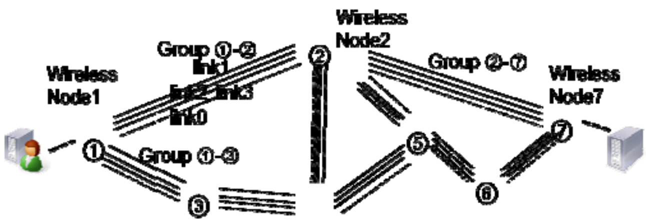

Fig. 1. Wireless Network Architecture

Wireless nodes are supposed as wireless terminal, and they have routing, adhoc, and multi-hop functions. Every node has multi wireless links like IEEE802.11a, IEEE802.11b, IEEE802.16 (WiMax), and IMT2000. The lowest RF link is used as the control links for the purpose of sending a network characteristic data or message of switching links. Also, Antenna of each node is supposed as non-directional.

Moreover, the network condition is changed over time by node's movement or radio interference like trees or buildings. A data transmission is carried out by ordering user request from a server to a user terminal.

B. System Architecture
The system architecture is organized three layers, including the physical layer, the network layer, and the application layer in Fig 2.

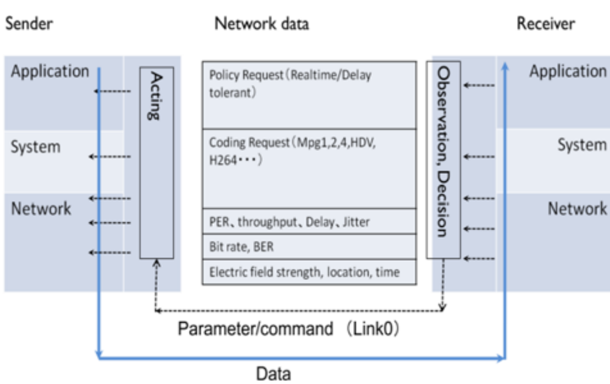

Fig. 2. System Architecture

When transmission data sent from sender to receiver, network data from each layer is observed through link0 that is the control link as explained in the previous section.

In the application layer, a user application is detected for the decision of user policy. A user policy is assumed to various types like video, VoIP, text, connectivity (emergence purpose like disaster) and so on. These policies are used for the decision formula which will be mentioned in the later section.

The system layer collects type of coding and performs coding functions including transcoding of a video coding to another one, such as from/to Motion JPEG to/from MPEG1.

The network layer observes network conditions such as the value of PER, throughput, delay, jitter, BER, electric field strength, and so on.

Network data from each layer is observed, and the decision making is held with crossing through layers. Then, the message of prefer link or route is sent through link0, and a reconfiguration procedure is acted at both sender and receiver nodes.

3 Methodology

As the previous research [8], the cognition cycle is introduced to our proposal method. The cognition cycle is consisted of three stages; the observation stage, the decision stage, and the acting stage. Each stage is continuously cycled in order to perform link or route configuration.

A. Observation Stage

Network data is continuously observed through each layer at this observation stage. Wireless network condition varies depending on the movement of nodes or radio interference. Therefore, CWN needs to parse these stimuli to select the available solution for providing the performance from user requests.

In this paper, our supposed system observes application types in order to decide user policy which is depending on the specific services or media. Also, physical characteristics like coding, PER, throughput, delay, jitter, BER, and electric field strength are observed. Those parameters are used for understanding stimuli from user environment.

B. Decision Stage

Decision making is held to maintain QoS in this decision stage. When the network condition is changed, the proposal system will seek the suitable link and route by the calculating from the values of network characteristics like user policy, throughput, BER, and so on. We introduce AHP for the calculation of link, and extend AODV for the decision of suitable route.

1) Link Selection

AHP is one of multi-attribute decision making and structured techniques for dealing with complex decisions. It was developed by Thomas L. Saaty in the 1970s [9]. By structuring a decision problem hierarchy, AHP provides us quantifications of its elements and evaluations of alternative solutions.

For example, when the suitable link between neighbor nodes is solved by AHP, the hierarchy of the problem is first structured. That is, goal (To decide suitable link of wireless node), criteria (network characteristics such as delay, PER, throughput, and

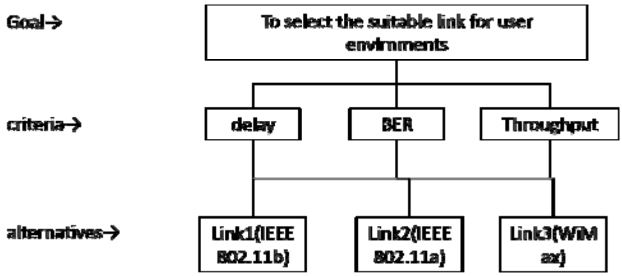

Fig. 3. Example of Hierarchy on AHP

so on), and alternatives (wireless links such IEEE802.11b, IMT2000, and satellite network, and so on).

Then, paired comparisons of criteria and alternatives are calculated for the priority value on AHP. Assume that we are given n as the number of criteria/alternatives, and $w_1, w_2, \ldots, w_n$ as the weight of each criteria/alternative, and paired comparison of each element is express as $a_{ij} = w_i/w_j$. These paired comparisons are expressed as the following paired comparison matrix A.

$$A = \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_j} & \cdots & \frac{w_1}{w_n} \\ \cdots & & \cdots & & \cdots \\ \frac{w_i}{w_1} & \cdots & \frac{w_i}{w_j} & \cdots & \frac{w_i}{w_n} \\ \cdots & & \cdots & & \cdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_j} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \tag{1}$$

We have multiplied A on the right by the vector of weights $w=(w_1, w_2, \ldots, w_n)^T$, and then the result of this multiplication is λw. That is λ is the eigenvalue of A.

$$Aw = \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_j} & \cdots & \frac{w_1}{w_n} \\ \cdots & & \cdots & & \cdots \\ \frac{w_i}{w_1} & \cdots & \frac{w_i}{w_j} & \cdots & \frac{w_i}{w_n} \\ \cdots & & \cdots & & \cdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_j} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ \cdots \\ w_n \end{bmatrix} = \lambda \begin{bmatrix} w_1 \\ \cdots \\ w_n \end{bmatrix} = \lambda w \tag{2}$$

Then, priority is defined as;

$$priority = \frac{w_i}{\sum w_i} \tag{3}$$

At this time, we introduce network data like the following in order to acquire network environment for the alternatives.

$$Si = \left(\frac{n_i - l_i}{u_i - l_i} \right) \times 10 \text{ (In case of throughput)} \tag{4}$$

$$Si = \left(1 - \frac{n_i - l_i}{u_i - l_i} \right) \times 10 \text{ (In case of BER, PER, latency, etc)} \tag{5}$$

In the above formula, Si is the weight of each alternative, u_i and l_i are the upper and lower limits of the alternative, and n_i is the observed value from network.

We also adopt the value of consistency index (C.I.). C.I. expresses the characteristics of polynominal of A, and we accept the estimation of w if C.I. is less than certain threshold.

$$C.I. = (\lambda_{\max} - n)/(n-1) \tag{6}$$

In this paper, we propose the calculation of AHP based on each user policy like video, VoIP, or connectivity for decision making of the suitable link. For example, in case of emergency like disaster, connectivity is more important as user policy. Thus, the criteria like electric field strength and BER are weighed and calculated by the formula (3). Then, priorities of alternatives is calculated by (4) and (5), and the results are inserted for (3). Finally, each value of alternative is calculated by alternative priority multiplied with criteria priory, and the link with largest value will be decided as the best suitable link.

2) Route Selection

Our proposed system would change network route if the suitable link is not found or minimum requirement for user is not satisfied. When a network route needs to change, we introduced extend AODV for the decision of suitable route.

AODV is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad-hoc networks.[10][11] It is a reactive routing protocol, which means that it establishes a route to a destination only on demand base. Therefore, the connection is slower than proactive routing protocols like OLSR or TBRPF. But AODV is superior when the network condition changes so often or changes so slowly. [7].

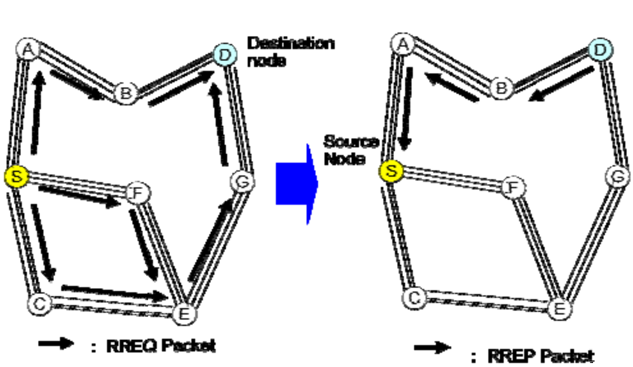

Fig. 4. RREQ and RREP

AODV builds routes using a route request (RREQ) and route reply (RREP). When a source node requires a route to a destination for which it does not have a route, the source node broadcasts RREQ packets across the network. When the other nodes receive those packets, and then update their routing information for the source node and set up backwards pointers to the source node in the route tables.

The RREQ contains the source node's IP address, current sequence number, broadcast ID, and the most recent sequence number for the destination node. A node receiving the RREQ may send RREP packets if it is either the destination or it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, RREP packets are sent back to the source node with setting the routing tables relatively.

3) Extended AOCV

We propose a extended AODV protocol by adding the link values and network conditions on each node for RREQ and RREP packets on each node from the source to the destination. The link values of each node are calculated by AHP as the previous sections, and those are set to the information of next node ID. Also, network characteristics values of each node such as delay, PER, throughput, and so on are added to RREQ and RREP packets. Then, a destination node receives all of the RREQ packets from the possible routes during certain unit time. Then, possible routes are compared to select the best route,

1) that can provide the maximum End-to-End throughput among all of the routes for video service, or
2) that can provide the minimum End-to-End delay time among all of the routes for VoIP, and
3) that can optimize the policy based AHP for Web service.

Through those comparisons, the best suitable route is decided by the policy of transmission data.

We propose to add the link values by AHP for RREQ and RREP packets, and those are set in the routing tables like Fig.5.

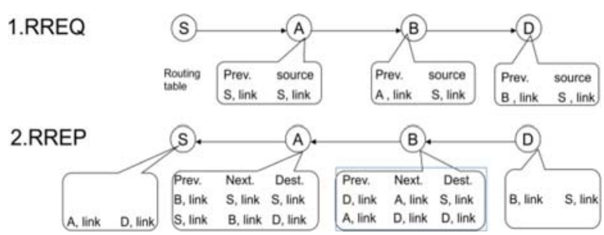

Fig. 5. Routing Tables by Extend AODV

C. Acting Stage

After the decision making of the suitable link or the route, a link or route will be changed in the acting stage.

In the proposed system, a control wireless link is assumed to use for a transmission of the control information. A control link is set to the lowest frequency bandwidth, and a node sends the information with a suitable link to the next node through the control link. Then, both nodes act the link change at the same time. A route change also acts as the same way of a link change.

The cognition cycle goes back to the observation stage after the acting stage, and it works to a link or route change relatively.

4 Simulation

In the simulation, ns2 (Network Simulator 2) was examined to evaluate the effectiveness of our suggested method. IEEE802.11a, IEEE802.11b, IEEE802.11g is used as the wireless links, and IMT2000 is used as the control link. The number of wireless nodes is set to two, and every node has the same wireless links. Then, only a source node moved with the same speed, and video data were transmitted from the source node to the destination node. The simulation conditions are the following table.

Table 1. Simulated Conditions

Item	**Simulation Content**
Nodes	Node0 moves from (10,5,5) to (300,5,5) with 2m/s Node1 is set to (10.5.5)
Anntenna	Non-directional
Transmission Data	320x240 MJPEG (15fps, 1/15 Compressed data) is send from node0 to node1.
Link Interface	IEEE802.11a/b/g. Each link has one channel.
Space	Free Space
Observed Parameters	Signal Strength, Throughput, Jitter, PER

In this paper, a link change is especially focus on the simulation. First, the simulation of IEEE802.11a, b and g is simulated under table1 conditions.

The Fig.6 shows the results of each node simulation. At Fig.6, throughput of IEEE802.11a is quickly down about 18sec, and the link is disconnected about 23sec. Also, IEEE802.11g is gradually down and disconnected about 145sec. IEEE802.11b keeps link connection although throughput is not so high.

On the contrary, the results of our proposal method are showed in Fig.7. Fig.7 shows that our proposed method keeps high throughput because the link selection is effectively worked under video transmission scenario. The wireless link is switched from IEEE802.11a to IEEE802.11g at 14 sec, and also switched IEEE802. 11g to IEEE802.11b at 132 sec. This results showed the proposed methods change the best suitable link to maximize the transmission rate with user policy.

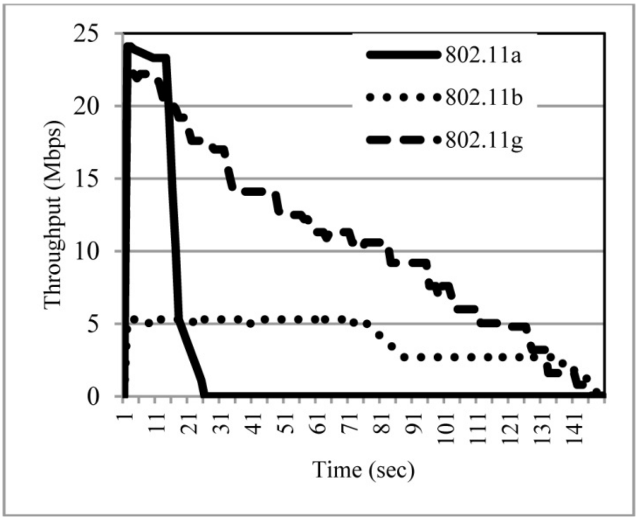

Fig. 6. IEEE 802.11a/b/g Throughput

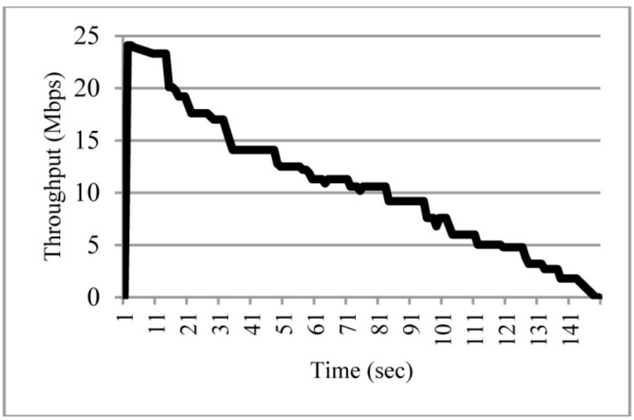

Fig. 7. Proposed Cognitive Wireless Network Throughput

5 Conclusions

In this paper, the transmission control methods in cognitive radio network considering with cross layers including user policies are introduced. Compared with giving fixed transmission rate, the our suggested methods can determines the transmission rate dynamically to achieve the maximum throughput by changing wireless links. The simulation result based on the video based data show that the proposed methods change the best suitable link to maximize the transmission rate with user policy. Therefore, the proposed method is shown in practical, efficient and reliable to support data transmission.

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