A machine learning based performance enhancement mechanism for reliable link in cognitive radio for wireless networks

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ABSTRACT

Cognitive radio is an efficient technology to avail the benefit of next generation wireless network by utilizing the available spectrum in a dynamic manner. Cognitive radio is used to enhance spectrum utilization and efficiency. Most researches in cognitive radio is done to improve spectrum efficiency and its utilization in dynamic manner. However least is done to improve the link reliability of cognitive radio for wireless networks link reliability is one of the major factor to enhance the network robustness. The main objective of our work is to show the application of machine learning algorithm to improve the network failures and thereby improving the reliability of wireless networks which are using cognitive radio in order to achieve next generation customer expectations.

Keyword: *wireless communication,failure,reliability,cognitive radio,machine learning technique.*

1.INTRODUCTION

1.1 Failure classification

Wireless services have newly enjoyed incredible triumph because users gradually more appreciate the ability to access or share information anywhere and anytime. In come back for these amenities, users have accepted that wireless links are unreliable with incoherent Quality of Service (QoS) in which tribulations (dropped or hung connections, variable data rates, delays, etc.) are regular occurrences. Although users consider these tribulations as inherent characteristics of wireless networks, as wireless services become more persistent and restore applications currently provided only in wire line networks, the question of reliability becomes more significant. The research in cognitive radio in previous decade was mainly focused on vacant spectrum of cognitive radio. however, least work is done to improve reliability of cognitive radio. [4]

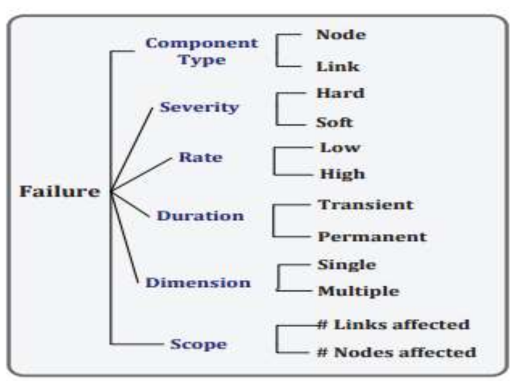

figure 1 failure classification chart[4]

As illustrated in Fig. 1, a classification based on the component type, severity, rate, duration, dimension and scope axes can be used to encompass the most important characteristics of failures in wireless networks[4]. analogous classifications with faintly different failure parameters have been formerly proposed and our classification includes all aspects discussed in the literature. The detection or evaluation of these failure parameters can help to devise better preclusion methods and aid the healing mechanisms to select the most appropriate approach, as will be discussed in Section V. The definition of each failure classification parameter is as follows.

1) Component type: This parameter indicates the component under failure. In wireless networks, two components can suffer from a failure: the nodes (fix or mobile nodes, base station or spectrum server) or the transmission links.

2) Severity: Two levels of failure severity can be identified: hard and soft. A hard failure occurs when the communication flow is totally halted. In contrast, a soft failure refers to a situation where the communication flow is not stopped, but the service that can be offered (bandwidth, QoS, etc.) is degraded.

3) Failure Rate (Frequency): The failure rate describes the number of times that a failure happens in a specified period. For example, a node failure due to power loss may happen once a month while a failure due to hardware defects happens once every two years.

4) Duration (Outage Time): A wireless network failure can be either permanent or transient. For example, if a user is moving away from a base station, the link failure with this base station will be permanent, while a channel fade causes a transient failure whose duration is determined by the mobile speed. 5) Dimension (Failure Cardinality): The failure dimension indicates whether an event results in single or multiple failures. A single failure dimension implies that, in a short period of time, it is unlikely that multiple failures will occur, whereas a multiple failures dimension indicates that, if a failure occurs, then there is a high probability that other failures will also appear somewhere else in the network. For example, a channel fade has a single failure dimension, whereas the appearance of an interferer has a multiple failures dimension.

6) Scope (Failure Propagation): The failure scope is related to the failure propagation concept. That is, a single failure might not only affect the component under failure but also influence the behavior of other components in the surrounding area. The failure scope indicates the area (number of links and nodes) affected by a failure. For example, a link bandwidth degradation in a wireless mesh network might affect the performance of other links in the neighborhood due to the congestion created by the re-routed traffic. However, in a single-hop network, a link degradation only has a local effect on the link.

By the proposed parameters, we try to cover different aspects of failure in wireless networks. The proposed classification is not completely orthogonal and the correlation between the parameters depends on the other factors such as network topology, type of redundancy and application. For instance, in general, permanent failures are hard failures; however, this is not always true and depends on other parameters. For example, a channel failure due to interference which forces a radio to change its operating frequency is assumed permanent. But, the severity depends on the availability of other channels. If the node quickly finds a new channel, the failure can be assumed soft, otherwise it is a hard failure.

It is also important to consider that a failure can be classified differently depending on the perspective. For instance, in a mesh network, a permanent node failure can be interpreted as a soft failure for other nodes as they are able to change their route. However, for the failed node (user) this failure is hard because it causes the user to get disconnected from the network. Next important point is the perspective and terminology of the failure. As another example, when a protected link is disconnected and the backup link is used, from the link perspective, this event is a soft failure which decreases the overall resource availability in the network. However, this link failure is masked and tolerated at the network operational level. Moreover, the classification of failures also depends on other parameters such as the applications and the specified QoS thresholds like acceptable delay and packet loss ratio.

1.2 failure causes

Failures in wireless networks occur for different reasons. In this section, we discuss and classify the most regular causes of failures and Table I presents their classification according to the formerly proposed criteria.[4]

1) Node Failure: There are a number of possible sources of node failure. For example, a power outage, hardware defects and harsh software faults are sources of hard node failures because the connectivity is totally lost. In a single-hop wireless network, there is no healing from such a failure unless a additional node is employed. In a mesh network, the node failure will affect numerous links, but the traffic going through this node may be re-routed. Note that, in both cases, all traffic originating from or targeting the failed node will be lost numerous types of backup resources may be used (if no backup resource is available, the node failure is permanent).For example, several antennas or transceivers can be used. If one element fails (partial failure), the communication link can still use the other antennas or transceivers. However, this technique might result in a lower data rate or link reliability after the healing. A backup power resource (for example, a battery) can also be used to cope with a main power outage. Top preserve its energy, the failure recovery algorithm might electro reduce the transmit power such that transmission is now only possible with closer neighbors or at a lower data rate .A similar situation can also occur for mobile nodes when the battery level goes below a threshold node failure is eternal and, depending on the availability of backup assets, it can be either a hard or a soft failure .Possible redundancies and the quality of hardware components are such that the rate of node failure is normally low. A node failure will affect a variable number of contiguous links and nodes depending on the network topology. However, it is improbable that several node failures will occur at the same time

2) Link Failure: Path loss, shadowing, multipath fading and interference are the major wireless channel impairments that can cause link failures. A wireless link completely fails when the performance metrics (bit error rate, signal-to-noise ratio, throughput, etc.) are not acceptable. However, in most cases ,the signal can still be received with degraded metrics. Bit Error Rate (BER) is the most widespread performance metric and link quality indicator in wireless communication. In general, the BER is inversely proportional to the Signal-to-Noise Ratio(SNR) at the receiver but the exact relation depends on the exact modulation scheme and diversity techniques that are used [15]. In a high SNR regime we further have that:

$$BER \; \alpha \; SNR^{-L} \quad (L>0) \qquad (1)$$

where L represents the diversity order of the communication system [6].

Path Loss: In a wireless network, when the distance between the source and the destination of a transmission link increases due to the users' mobility, the received signal power decreases thereby increasing the BER and packet loss and degrading the link quality. Let d be the distance between the transmitter and the receiver (assuming a constant noise and interference power), we then have:

$$SNR \; \alpha \; \frac{1}{ds} \qquad (2)$$

where n represents the path loss exponent which depends on the characteristics of the environment. In urban areas, n is generally between three and four [15]. Because the distance varies gradually, the failure caused by distance is a soft failure ,but it can become a hard failure as the nodes become farther apart. The failure due to distance is considered permanent because it cannot be assumed that the nodes will come closer in the future.

Environment Effects (Shadowing and Fading): Stochastic signal variations, such as shadowing and multipath fading, usually cause transient soft failures. For example, signal degradation due to a building shadow will disappear when the user moves away and small-scale fading causes large signal variation with a displacement on the order of the wavelength. Estimating the duration of those failures can help in implementing efficient recovery mechanisms. These

variations decrease the power of the received signal which in turn increase the BER [15]

.*Interference:* In a wireless environment, several users can simultaneously transmit on the same channel, which can create interferences. The SNR at the receiver is proportional to the inverse of the interference:

$$SNR = \frac{Pr}{N+I} \qquad (3)$$

where P_r is the power of the received signal, N represents the power of the noise and I stands for the total interference. Higher interference thus directly increases the BER of the link .Some technologies, such as spread-spectrum communications ,are more immune to interference than others (such as narrowband systems). Therefore, depending on the communication technique, the impact of an interferer can vary from a soft failure to a total link failure [6], [15]. In addition, the failure duration depends on the nature of the interferer and can be transient or permanent. For example, a cordless phone will create interference on a wireless network during the time of a conversation but, if a neighbor sets up his wireless net work on the same frequency channel, the failure will be permanent. Furthermore, due to the broadcast nature of wireless media, an interferer will usually simultaneously trigger failures on several links.

Cause of failure	Component type	Severity	Rate	Duration	Dimention	scope
Node failure	Node	Hard/soft	Low	Permanent	Single	Several node/links
Distance	Link	Soft	Average	Permanent	Single	Limited
Shadowing and fading	Link	Soft	High	Transient/permanent	Single/multiple	Limited
Interference	Link	Hard/soft	Average	Transient/permanent	Multiple	Limited
Traffic congestion	Link	Soft	Low	Transient	Single	Limited

Table 1 classification of most common causes of failure[4]

Congestion: In wire line networks, a high volume of traffic can generate packet loss and delays that can cause severe failures in higher layer communication protocols. In a wireless network, similar phenomena can occur. However, because the wireless channel is shared among several users, a source with a large volume of traffic will degrade not only the performance of his link but also that of the other surrounding users .For example, in random-access protocols such as in IEEE802.11, a node with a large amount of traffic will increase the contention delay (collision probability) of all users in the network [16]. Therefore , traffic increase in one node can cause failures somewhere else in the network. Special care should also be taken when classifying the cause of a failure. For example, when a node has several operational transceivers and one of them experiences a hardware failure (partial node failure as explained earlier), one of the operating links fails and the radio handles this failure by switching to other transceivers. This implies that we can model these types of node failure as a link failure and consider hardware problems as a new cause of link failures for multi-transceiver nodes. However, a failure in a spare transceiver which is not operational represents a degradation of hardware redundancy and reliability and can not be modeled as such as a link failure.

2 . Cognitive radio

2.1 what is cognitive radio

Nowadays, the radio resources and particularly the spectrum, are considered a very precious and scars resource, not because of their unavailability but because they are used inefficiently. Due to this fact a considerable research has been conducted recently for finding suitable and efficient ways to use the spectrum. In general, traditional wireless communication systems have fixed transmission parameters. In other words, their transmission frequency is fixed and the same in every location and instant of time, determined by regulatory standards. The recent popularity of telecommunications and wireless communications, has increased the usage of radio spectrum exponentially, in order to supply all the demand and improve communication parameters and Quality of Service (QoS), so new technologies need to be developed. These technologies have to deal with radio resources efficiently, they can be considered as radio systems with high intelligence and capabilities of adaption and awareness. This radio system is called “Cognitive Radio”. Cognitive Radio

Cognitive radio Such a radio automatically detects available channels in wireless spectrum, then accordingly changes its transmission or reception parameters to allow more concurrent wireless communications in a given spectrum band at one location. This process is a form of dynamic spectrum management.

2.2 cognitive cycle

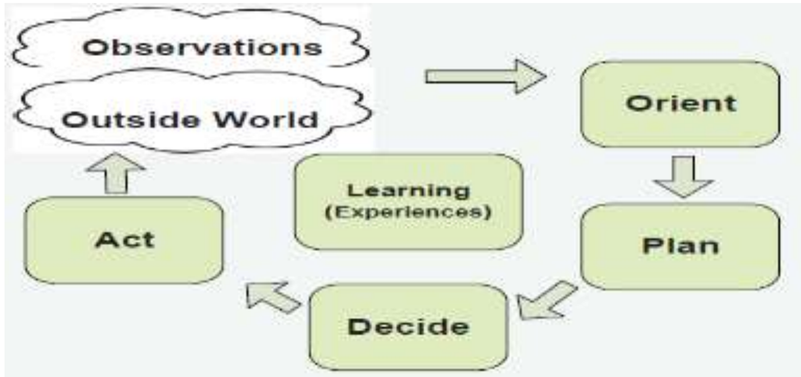

Figure 2 Cognitive cycle[4]

All the previously described capabilities are operating inside the framework of the CR cognitive cycle (Fig. 2). The cognitive cycle consists of five main stages completed by the learning stage. In the observation stage, the radio senses and identifies the environment to obtain a variety of facts about it. Spectrum awareness and location-awareness methods are part of this stage. During the orientation stage, the CR node adapts its architecture according to the priority and importance of the observed events. Based on the available resources and environmental parameters, the CR creates different plans, decides which plan will be selected and applies the decision by changing the required parameters in various layers. Finally ,the CR node can learn from its observations and decisions for future uses.

2.3 Modified cognitive cycle for failure management

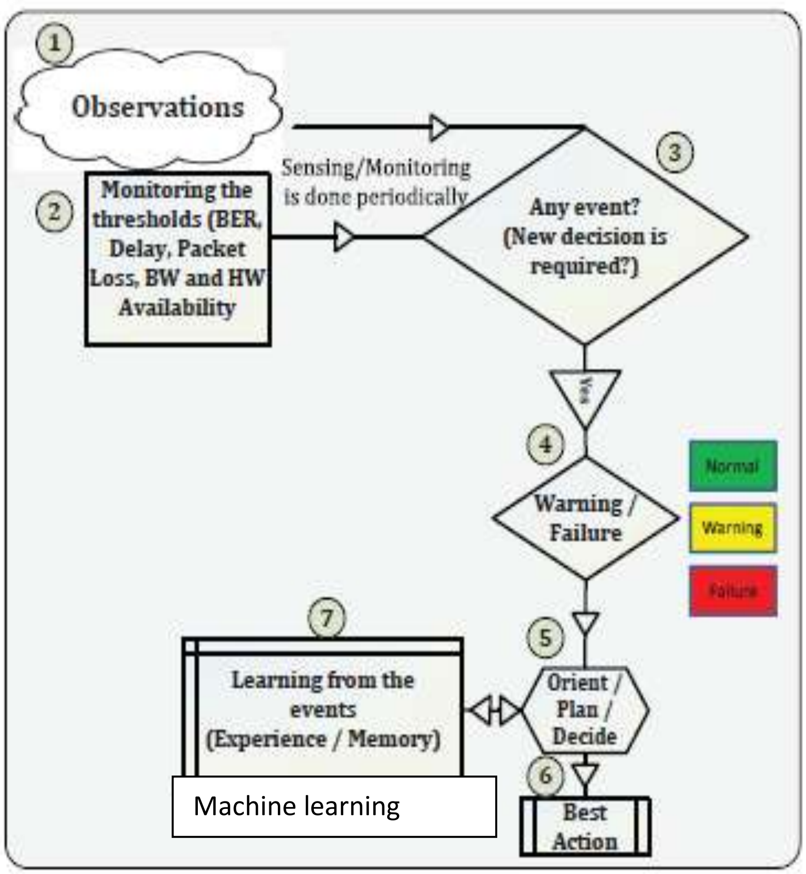

Figure 3 Modified cognitive cycle for failure management[4]

Our main objective is to design a wireless system architecture that can counter wireless failures and improve wireless network reliability using approaches similar to those currently in place in wire line networks. As will be discussed in this section, considering its cognitive features and intelligence the Cognitive Radio has the necessary attributes to achieve this objective. The modified CR cognitive cycle presented in Fig. 3 illustrates the inherent capability of CRNs to prevent or recover from failures to improve wireless network reliability. In stage 3, after the environment observation phase and the monitoring of the performance and QoS parameters(stages1 and 2), the cognitive radio detects whether any new event has occurred or may be occurring in the near future. To make the most appropriate decision, the CR node classifies the new event as a Warning or Failure in stage 4. In the former case, the CR deploys failure prevention measures. For example, if a CR mobile station detects that its distance from the base station is increasing, it can switch to a lower modulation and coding to prevent path loss failure. In the later case ,the CR node characterizes the failure according to the failure classification chart (Fig. 1) and uses the appropriate protection and restoration techniques (stages 5 and 6). The CR node can also learn from the current experiences and observations to help it in the development of more efficient plans in the future.

conclusion

The present generation wireless communication networks demands for reliable communication. Cognitive radio is used to enhance the reliability in present day wireless network to cope with various types of failures in networks. Cognitive radio used to learn from failures to enhance it quality of service.

We proposed a method to make cognitive radio learn using machine learning algorithm (SVM/KNN) and evaluate the performance of cognitive radio learning with and without machine learning.

The simulated results shows the performance of various machine learning algorithms under two different types of dataset (one for evaluating QOS and another for evaluating type of failure in the network).

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