DDWR White Paper

Dynamic Wireless Routing for D-Link's Mesh Solution

White Paper
April, 2007

Abstract

Providing high mobility and improved serviceability, this unique and dynamic wireless routing protocol offers rapid convergence to ensure resiliency against link and node outages, thus ensuring there is no system-level single point of failure. The protocol uses radio link quality to select the best path for routing, thus maximizing user throughput to reduce the delay and jitter in fast-changing wireless environment. With this protocol, tracking of continued connectivity to routing neighbors, detection of broken link, and elimination of routing-loops are all made possible, hence improving the adaptability and stability of routing. D-Link's wireless routing protocol is highly flexible, inherently fault-tolerant, and works well with mobile and fixed wireless mesh networks, out-performing its peers by significant margins for a wide variety of user applications.

D-Link
Building Networks for People

Understanding the Business Climate

With recent technological advancements in computer and wireless communications, mobile wireless computing has seen increasingly widespread use and application. Unconstrained by wires, users with mobile computing devices can travel freely at their convenience, while communicating with each other even in environments where there are no fixed infrastructure. In such environments, a Mobile Adhoc network (MANET) can be formed or by using mobile wireless mesh network. A mobile wireless mesh network is an autonomous system of wireless mobile routers (and associated hosts) which can move randomly and re-organize themselves into an arbitrary network without any underlying backbone and infrastructure.

Besides mobile wireless mesh networks, recent commercial applications of fixed wireless mesh networks have also emerged. One example of such applications is “community wireless networks,” which are used to provide broadband Internet access to communities that previously do not have such access. In such fixed “community wireless networks”, each wireless router in the network not only provides Internet access for attached users but also becomes part of the network infrastructure and can route data through the wireless mesh network to its destination.

A routed wireless mesh network is highly flexible and inherently fault-tolerant. It simplifies line-of-sight issues and extends the reach and coverage of the network with minimal amount of network infrastructure and interconnection costs. Hybrid wireless mesh networks are also possible, where some mesh routers are mobile and others are not.

Regardless of whether mobile, fixed, or hybrid, wireless mesh network have some salient characteristics, such as: highly dynamic, autonomous, peer-to-peer, multi-hop, computing power, and often limited bandwidth. The wireless mesh networks are highly dynamic for two reasons. First, the routers themselves may move (e.g. in mobile or hybrid wireless mesh networks), causing fast topological changes. Second, even if the routers themselves don’t move (e.g. in fixed wireless mesh networks), the radio link qualities can change very quickly because of interference, geographical, and environmental factors.

From these characteristics of wireless mesh networks, it is clear that the desired properties for wireless mesh routing protocols should have:

- Distributed operation
- Quick convergence (to enable faster mobility)
- Scalability for handling:
  - Large quantity of small devices
  - Limited bandwidth and computing power
- Proactive operation (to reduce initial delay)
- Ability to take radio link quality and link capacity into account when selecting routes
- Loop-freedom
- Security

In addition to traditional routing protocols designed for wired networks (e.g. OSPF [1], RIP [2]), a number of routing protocols designed for mobile adhoc networks have also been proposed. They are commonly broken down into two broad classes:

1. Reactive routing protocols (i.e. AODV, DSR, TORA), which only discover and maintain routes on demand. By adapting to the traffic pattern on a demand or need basis, energy and bandwidth resources can be utilized more efficiently at cost of increased route discovery delay.
2. Proactive routing protocols (i.e. DSDV, OSLR), which always maintain routes to every possible destination on the assumption that they may be needed. In certain contexts, additional latency incur by reactive routing protocols may be unacceptable. Proactive routing protocols in these contexts may be more desirable if bandwidth and energy resources permit.

The traditional routing protocols (e.g. OSPF, RIP) are designed for wired networks and is unable to deal with fast topological and radio link quality changes that are common for wireless mesh networks. Many existing adhoc routing protocols mentioned above have made significant improvement to deal with fast topological changes. The simulation results of these improved protocols however still indicate unacceptable level of packet loss and long delays during high mobility. Most existing protocols, traditional or adhoc, moreover have severe scalability and stability issues in adapting to fast radio link quality changes common to both mobile and fixed wireless mesh networks.

In order to solve these problems, D-Link therefore introduces the D-Link Dynamic Wireless Routing (DDWR) protocol.

D-Link's Strategy and Solution

D-Link Dynamic Wireless Routing (DDWR) protocol is an adaptive, distributed, proactive routing protocol designed specifically for wireless mesh networking.

In DDWR, each router maintains a routing table that contains all the information necessary to forward a data packet toward its destination. Each routing table entry is tagged with a destination sequence number which originates from the destination node. This helps identify the stale routes from the new routes, thus avoiding routing-loop.

In DDWR, each node keeps track of its continued connectivity to its neighbors. The broken link can be detected by the layer-2 protocol, or by using layer-3 enhanced wireless hello protocol. To maintain the consistency of routing tables in a dynamically varying network, each node periodically transmits updates, and trigger updates when significant new information is available. In addition to the sequence number mechanism that eliminates the routing-loops that haunt most of the distance vector routing protocols, a unique messenger mechanism is introduced to further speed up the convergence, and to further reduce the routing overhead by making the re-convergence as local. To improve the adaptability and stability of routing, DDWR in addition maintains each destination multiple routes information that can be used for fast failover and load-balancing. All these routes are guaranteed loop-free at any instant.

DDWR works well with mobile and fixed wireless mesh networks, and offers very attractive combination of desirable features for wireless mesh routing protocols. These include:

- Fully distributed with resiliency against link and node outages, ensuring there is no system-level single point of failure
- Dynamic, adaptive, proactive routing, with self-forming, self-healing, and reduced initial delays
- Fast convergence that enables high mobility and greatly improved serviceability
- Flexible adaptation to topological and radio link quality changes
- Maximized user throughput by taking radio link quality into consideration, which is very important for wireless mesh networking
- Highly scalable with low computational and communicational overhead, which is especially important for large wireless mesh network deployment
- Simple and easy to implement with loop-free at any instant
- Multiple loop-free routes to each destination for fast failover and load-balancing
- Security for all routing packets with encryption and authentication
- Support for multi-radio, multi-hop wireless mesh networks
- Unique capability of recognizing temporary wireless fades from actual loss of wireless links due to mobility, router failure, and other reasons

DDWR has been implemented and used in many customer sites. Many simulation and experimental results have shown that DDWR works well with mobile and fixed wireless mesh networks, with superior performance over peers for a wide range of user applications.

Simulation results of DDWR in comparison with four other prominent MANET routing protocols, AODV, DSR, OLSR and DSDV have also shown DDWR has having overall having the highest packet delivery ratios with lowest average delays, most resilient to both mobility increase and traffic load increase, and performs especially well under stressful conditions (i.e. high mobility, heavy traffic), out-performing its peers by significant margins.