ENERGY-EFFICIENT PROTOCOL IN OMNET++ SIMULATION ENVIRONMENT

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***Abstract**: New idea for energy-efficient extension for OSPF protocol is presented. New concept is based on Dijkstra's algorithm, which recalculates shortest path each time, when metric is updated. There is introduced in OSPF new metric's value based on traffic load on routers' interfaces.*

***Keywords**: energy-efficiency, OMNeT++ simulation environment, OSPF routing protocol*

***ACM Classification Keywords**: I.6 Simulation and Modeling*

Introduction

Green networking is becoming more and more popular trend. Bigger power usage of information communication technologies limit the wireless networks performance. This problem touches also wired networks, because energy costs are big part of overhead costs for network devices. Also carbon dioxide emissions reduction is becoming a significant problem. Many public organizations and internet service providers report statistics of growing trend for network energy requirements [Bianco, 2007], [Qureshi, 2009], as well as for carbon footprint.

One of the interesting examples is energy consumption of Telecom Italia network, which reached more than 2TWh in 2006, i.e. 1% of the total energy demand in Italy. British Telecom 2.6TWh in 2008, Deutsche Telekom more than 3.5TWh.

To support further development of telecom operators there is a need to run more sophisticated architectures, more complex operations in a scalable way [Chabarek, 2008]. Also from the Future Internet point of view, it can be said, that energy awareness is becoming an important part of the network design. Interesting challenge is creating mechanisms for network equipment enabling energy savings. An idea how it can be done is following: adapting network capacities and resources to current traffic loads, in the same time not forgetting about Quality of Service (QoS).

There is done broad spectrum of research focusing on energy aware infrastructures, applications, transmission and adaptive control of device activity, that form a network.

Open-Shortest Path First Protocol

Open Shortest Path First is an adaptive routing protocol for Internet Protocol networks [Azzedine, 2003]. Uses a link state routing algorithm, belongs to the group of interior routing protocols, operating in a single autonomous system. For IPv4 is defined as OSPF Version 2, for IPv6 – OSPF Version 3.

OSPF is one of the most widely-used interior gateway protocols [Haider, 2011] [Daniluk, 2012] in large networks. OSPF as an interior gateway protocol routes IP packets inside a single routing domain, i.e. autonomous system.

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A topology map of the network is built based on link state information from routers. OSPF is able to detect changes in the topology, like link failures. There is computed the shortest path tree for each route using a Dijkstra's algorithm. On each router is kept link-state information, called link-state database (LSDB), which is a tree image of the entire network topology.

Copies of LSDB are periodically flooded in the network on all OSPF routers. There are used cost factors in OSPF routing policies in constructing a route table. Cost factors can be following: distance (round-trip time) in the network.

OSPF does not use a TCP/IP transport protocol (UDP, TCP), but is encapsulated in IP datagrams.

Link State Advertisement (LSA) is used to inform all other local routers in the same OSPF area about the router's local routing topology. LSAs are not flooded out on all interfaces, but only on those that belong to the appropriate area. Thanks this detailed information can be kept localized.

There are different types of LSA.

Some of them announce presence of the router and lists of the links (also metrics) to other routers or networks in the same area. These LSAs are flooded across their own area only, it is type 1: Router LSA.

On the other hand we can see Area Border Router (ABR), which learned on one of its attached areas, summarizes and sends it out on other areas it is connected to. The summarization provides scalability by removing detailed topology information for other areas. Routing information is summarized into just an address prefix and metric.

Power management mechanisms

Modern power management mechanisms must deal with optimization at all levels of network structure. To do this there are used power scaling and standby capabilities, to decrease energy demands [Bolla, 2010] [Zhang, 2010].

The smart standby puts a device in a very low energy mode, in which only some vital functionalities are provided. It means, that standby capability can be applied in devices, that will be not used for a longer period of time.

The dynamic power scaling reduces the energy requirement of a network [Cuomo, 2011] by scaling its performance. There are two main families of power scaling approaches:

Adaptive rate techniques (AR): scaling the device's processing capacity, transmission, reception speed of the network interface.

Low power idle techniques (LPI): using short inactivity periods by putting a device into low power state. They are presented in fig. 1.

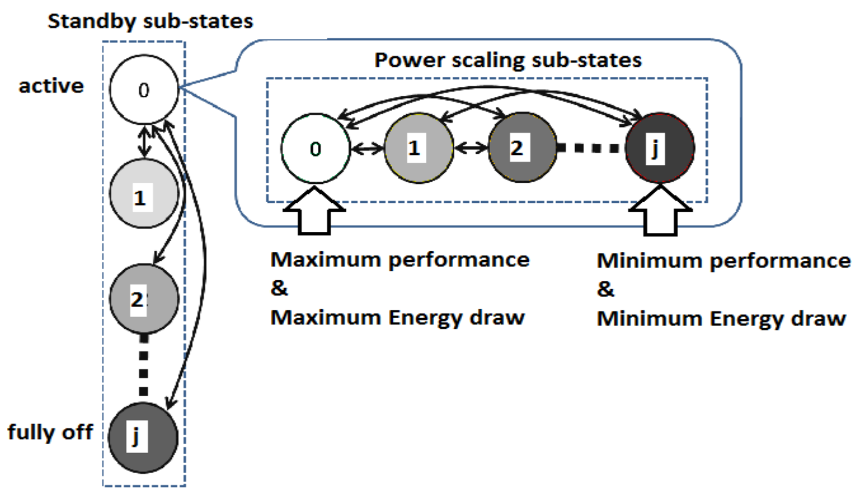

Fig. 1 Power scaling and standby power states

It is good to underline, that most personal computers follow ACPI (Advanced Configuration and Power Interface) specification defining a number of power-aware states, where is used scaling down processor voltage and clock frequency in case, when processor is in stand-by mode.

Different situation is for typical network devices, where is not implemented any energy saving mechanism.

An interesting idea would be using Green Abstraction Layer (GAL) [Bolla, 2010], interface between monitoring, control and hardware for exchanging data informing about power status of the device. It is built in order to hide the implementation details of energy saving approaches.

The Green Standard Interface is a simple internal interface of the „Green Abstraction Layer" (GAL) for exchanging power management data among data-plane elements and processes realizing control plane strategies. Important fact is creating power domains, building power management Quality of Service (QoS) by defining higher and lower level power states differentiated with frequency and voltage.

GRIDA algorithm

In one of the papers [Bianzino, 2012] is presented a new algorithm, called GRIDA, which is based on OSPF and extends its functionality. This algorithm may be used in networks, where a Link-State routing algorithm like OSPF is running.

The key idea of GRIDA is taking independent decisions, optimizing a selfish utility function at random time intervals.

What's more, there is no centralized knowledge, like Traffic Matrix, routing paths, but only LOAD and ENERGY COST of incident links and PERIODIC LSA reporting the network state.

If the network is congested or disconnected, then the node is forced to turn on all its interfaces (all-on configuration).

New possibilities for functionality of OSPF simulator in OMNeT++ environment – new author's approach

The main idea is introducing new elements to OSPF protocol's structure. The key feature is extending LSA Update messages, where routers get energy values of adjacency links. Thanks this they can, in a distributed way, control the energy states of their interfaces.

Nodes share information about the incident link load or power consumption through the link-state protocol.

There is also no centralized knowledge, LSAs (sent when change of the network topology, increasing traffic load) are reporting the network state and can suggest new energy states for other router's interfaces.

New: LSAUpdate packets are introducing updates based on following criteria: energy-efficiency.

In already done experiments a simulation environment for computer networks, called OMNeT++, is used. An example of network's scheme in OMNeT++ simulation environment is presented in fig. 2, nowadays there are done tests improving OSPF simulator in OMNeT++ environment.

The aim of this work will be further improving OSPF simulator in OMNeT++ environment, where unused links of routers, can be turned off or switched to different energy states, thanks this the energy can be saved and the computer network can work more efficiently.

In fig. 2 is presented an example network scheme, where routers R1 and R2 are exchanging with "energy information" like traffic load, current energy state of their adjacency links. Thanks this their routing table can be built also based on energy criteria of the links.

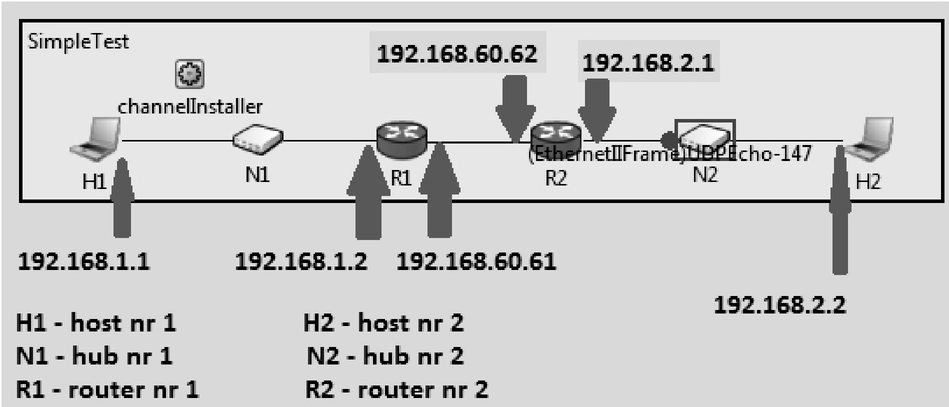

Fig. 2 OMNeT++ simulation environment, simple network presented

Nowadays is finished implementation part for following extension for OSPF protocol in OMNeT++ simulation environment - on each interface of the router is analyzed traffic load, like bits/second on each interface.

If this limit is exceeded, then link state cost is increased. This means, that there is changed metric of particular link. When link state cost is changed, then there is run function to recalculate the routing table of the router. When this is finished, Link State Advertisement (LSA) packets send new Link State topology to other routers, i.e. there is new version of Link-State Database (LSDB) on each router. This is done to balance the traffic load on the routers' interfaces. This is first step to optimize energy usage by routers.

Having possibility to balance the traffic load on the interfaces and combining this with Dijkstra algorithm used in OSPF, can be next introduced "power levels" of router's interfaces based on the traffic load on them.

Conclusion

There was extended OSPF simulator in OMNeT++ environment. The work is still in progress.

Currently – Dijkstra's algorithm is run each time, when metric of router's link is changed. Router's link metric is changed, when traffic load exceeds set limit for the interface in order to keep load balancing. The aim of this solution will be to control energy states of router's links.

Energy-efficiency can be understood currently as keeping load balancing for router's links. Thanks new functionality the routers will be able to exchange also with energy usage information of their links, thanks this there will be possibility to control usage of routers' interfaces, used and unused connections, can be controlled activity on the links. If necessary the links can be turned off, or can be switched to the different energy states, which aim is to save the energy and cut the costs in big computer networks.

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