

Routing metric

B.A.T.M.A.N. routing metric is based on link loss probability measured with broadcast messages. Then a number of solution have been introduced to penalize long route (HOP_PENALITY) and to favour nodes that offer multiple interfaces (interface bonding and alternating). This approach has been shown to work quite well, outperforming other mesh network routing protocols [4].

Unfortunately the simple metric used clearly has some limitations. I start exposing two simple situation in which B.A.T.M.A.N. protocol does not select the best path, then I will list a series of possible improvements that can solve these problems. Finally I implement one of the improvements experimentally showing that it solves the exposed problems.

Link bit-rate

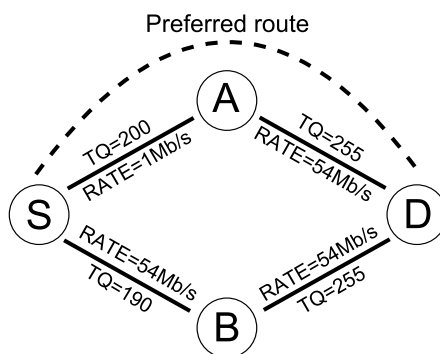


Figure 6: Network with links having different bit-rate. The current metric consider only loss-rate so the path with the slow link is chosen.

The current routing metric does not consider the bit-rate of the link in computing its quality. In other words, in a situation like the one depicted in figure 6 the path with minimum loss rate (but less bit-rate) is chosen albeit the other will offer an higher throughput.

This can be a very common situation both in case of heterogeneous devices with different characteristic, and also in presence of bad links that can only work at the minimum bit-rate.

I will state that there is not any connection between the capacity of a link, and its capability of deliver broadcast packets of few bytes.

Multi-hop penalisation

The current implementation of B.A.T.M.A.N. penalize long route multiplying actual transmission quality for a special coefficient before the OGM re-broadcast. This coefficient is called HOP_PENALITY, and its default value is $\frac{245}{255}$.

I will state that this implementation can introduce routing decision error that penalize

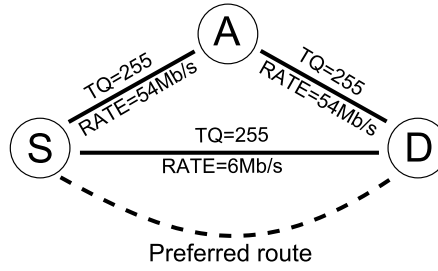


Figure 7: Routing example showing a situation with two possible path from *S* to *D*. One is a slow direct link, the other is a 2-hop path composed of two link with a better bit-rate. Due to `_HOP_PENALITY` the slow link is chosen.

the performance. In fact in a situation like the one depicted in figure 7, B.A.T.M.A.N. will select the slow direct link instead of the 2-hop faster link.

In general, in an ideal situation with no losses, the protocol metric take only into account the number of hops. This can lead to wrong routing decision, because the least hop metric has been shown to work badly in wireless network.

Improvement proposals

As evidenced, measuring loss rate of little broadcast packets sent at 1 Mb/s (or 6 Mb/s in a pure 802.11g network) does not tell much about the quality of a link. The unique information that we have is if the link is usable or not.

A number of additional information can be useful in order to take better routing decision, for example:

- Unicast link bit-rate
- Loss rate measured at various bit-rate
- Channel occupation percentage reported by the network card
- Load of the node

Some of these information are quiet simple to obtain and use, while other are more difficult to obtain (they can be driver dependant) and to insert in the routing metric.

The most simple information to collect and use is the unicast link bit-rate. This additional information can be used to estimate the achievable throughput of a path solving both the described problems and improving the overall network performance.

The implementation can be divided into two steps. First OGM structure should be changed in order to contain information about each traversed link. Second a new routing metric that consider the additional information should be developed. In this way, after the first phase, there is the possibility of testing many possible routing metrics, opening an interesting research area that surely will lead to performance improvement.

OGM structure

0	7	8	15	16	23	24	31	32	39	40	47
Packet type		Version		Flags		TQ		Sequence ...			
... Number				Previous ...							
... Sender				TTL		num. hna		num. hop		gw. flags	
... HNA list ...											
... HOP list ...											

The structure of OGM packet has to be modified in order to contain the information about each traversed link. Before the broadcast of an OGM each node enqueue this local link information, in this way the protocol become a sort of "path vector", in figure 8 is depicted this mechanism. Another advantage of this implementation is that each node knows the information about all the link toward all the originator nodes, in this way there is also the possibility to use the additional information to find out independent paths, so allowing in the future to implement multipath routing. Link/node attributes written in the OGM in the simple implementation based only on link bit-rate are:

- **Interface MAC address:** the MAC address of the interface that is going to broadcast the OGM.
- **Local TQ:** the value of TQ towards the previous hop (that is one of my direct neighbours).
- **Bit-rate:** the current bit-rate towards the previous hop in the path. This value is red from the driver.

Also the number of hops is written in OGM and updated at each hop. In future implementation, at this information can be easily added some other parameter to refine the routing decision, such as node load.

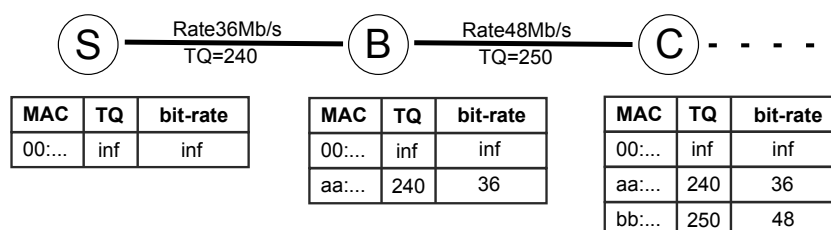


Figure 8: Each node enqueue to the received OGM its MAC address, the local TQ, and the bit-rate (and possibly other information) of its local link toward the previous hop. Also the hop count is increased. Then The OGM is rebroadcast.

PCE Routing metric

With new OGM, for each path, we know its length L , together with the local transmission quality TQ_i and the unicast bit-rate UR_i of each link i in the path. The new metric must take into account both the global path characteristics and the local link parameters.

We start estimating, for each link i , its capacity considering both its physical bit-rate and also the TQ value, that is a measure of the loss rate. We define the physical capacity estimation PCE as:

$$PCE_i = TQ_i UR_i$$

Now, the physical capacity estimation of the entire path can be defined as the minimum local PCE among all the link forming the path:

$$PCE = \text{Min}_{i=1}^k (PCE_i)$$

This value does not consider the length of the path. In order to consider path length, when two different path A and B are compared, a special coefficient $\Delta = \frac{L_A}{L_B}$ is used to take into account the difference in length of the two paths. A route change from path A to path B occurs if:

$$\Delta PCE_A > \frac{1}{\Delta} PCE_B$$

The Δ coefficient is not defined as the absolute difference in path length. This is because an unitary increase in the length have more weight if the path is short than if the path is already long. For example, if a candidate path have double length compared to the current best one, it must offer 4 time more physical capacity in order to be chosen.

Metric hysteresis

As evidenced in some research, B.A.T.M.A.N. and other routing protocols for mesh network suffer of a phenomena called route flapping. In other word many route change occurs, especially in presence of multiple similar path, and this can destroy the performance.

The simple introduction of a constant hysteresis can reduce this problem. In the experimental implementation, an increase of 5% of the described metric, in respect of the actual best route, is required for a route change. A further investigation on this aspect, in order to find out the best hysteresis technique and value to solve the route flapping problem, is out of the scope of this paper.

Measurements

The test-bed is composed of four laptop equipped with Atheros wireless card. The Ath9k driver has been used, this driver is fully compliant with the new Linux wireless configuration API cfg80211, allowing to easily obtain the per-station bit-rate used to compute the PCE. The implemented rate adaptation algorithm is derived from Minstrel. This algorithm is designed to find out the bit-rate offering the highest throughput, testing at a regular basis all the available rates. The B.A.T.M.A.N. version used is 2011.1.0 with

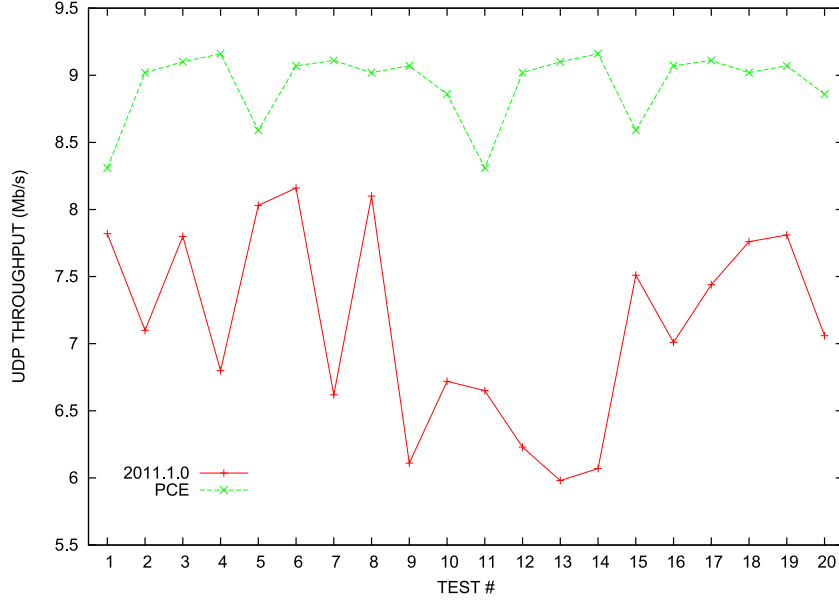


Figure 9: Throughput obtained in 10 seconds UDP stream tests respectively with B.A.T.M.A.N. 2011.1.0 and the modified version based on PCE metric.

the default configuration parameter (OGM interval of 1 second, aggregation disabled and bonding disabled).

The experiment consists on measuring the throughput of 10 seconds UDP stream. An interval of 120 seconds has been introduced between two consequent tests, this is to avoid any dependency between tests, allowing the TQ values for all the link to converge to the maximum. The network topologies examined are those depicted in figure 6 and 7. The objective is to show that the metric based on PCE selects the best route, and to measure the difference in term of throughput between the two implementations.

In the first topology, node D is not reachable directly from node S, but only through node A or B. The difference between the two paths, is that the one through node B is composed of links having higher bit-rate than those composing the other path. In this case B.A.T.M.A.N. choice is fairly random, because the TQ of the two paths is almost equal. A metric based on bit-rate, instead, should chose the fastest path.

The measurements, reported in figure 10, shows that standard B.A.T.M.A.N. achieved throughput is quite inconstant. This is an effect of the variable path chosen, in fact from the experiment it is emerged that the preferred route changes many times. This can come from the absence of hysteresis in the routing metric.

The proposed version, based on PCE metric, performs better because the path through node B is constantly used. The hysteresis introduced also protect the optimal choice from occasional losses of OGM, that have not to be considered as a defect in the link.

In the second network, the node D is reachable from node S directly, or via node A. The direct link work at low bit-rate (5.5 Mb/s), while the other two links work at 54

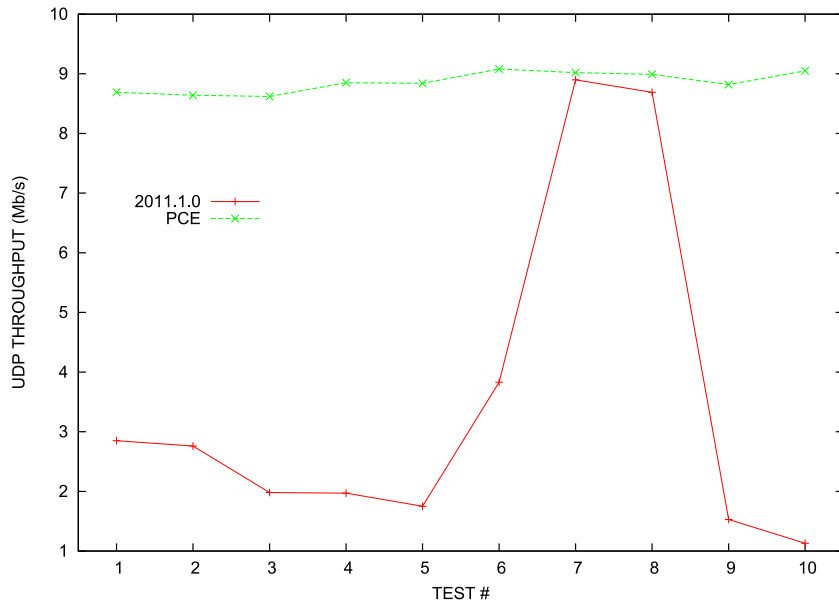


Figure 10: Throughput obtained in 10 seconds UDP stream tests respectively with B.A.T.M.A.N. 2011.1.0 and the modified version based on PCE metric.

Mb/s. All the links show maximum TQ (255), so standard B.A.T.M.A.N. tends to select the direct link, because the HOP_PENALIZATION mechanism penalize the fastest multi-hop one path.

The results obtained are reported in the graph 10. The throughput obtained with the PCE metric, is about 3 times more the average throughput obtained with the standard version and is very stable. As anticipated standard B.A.T.M.A.N. register poor performance due to the HOP_PENALIZATION and, in general, due to weakness of the TQ metric that does not consider link bit-rate.

Conclusion and future work

This work gives a better explanation of some aspects of B.A.T.M.A.N. routing protocol, evidencing some of its drawbacks, especially regarding the current routing metric. A detailed analysis of the protocol overhead on regular topologies has been exposed, and a simple modification of the protocol has been described and implemented, to show how the exposed routing problems can be solved.

In the future a more deeper study on the routing metric has to be done. In fact some aspects remain open, for example those regarding the presence of multiple radio interface, and in general the measure of the interference in the same flow (auto-interference) and between different flows. The proposed modification can be the base for these future improvement, because it easily allow to add whatever information about nodes and links in OGM messages.

References

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