

Supporting Real-time Communication in Wireless Mesh Networks

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Abstract: Wireless Mesh Networks are a key technology for providing wireless broadband access to communities and rural development areas, as they do not require any expensive wired backbone. They offer increased network resilience to network failures due to self-organization and redundancy in the network. But the noisy and erroneous wireless communication channel affects the quality of real-time communication. User-received transmission quality may become unacceptable due to artefacts, stumbles, interruptions etc. We propose a new architecture that exploits path diversity and multi-stream coding to cope with link quality variations and to reduce the effects of the wireless medium. Moreover, the architecture dynamically adapts to changes in the network.

1. Introduction

Wireless Mesh Networks (WMNs) caught on as a technology for increased network coverage [1]. Several research networks (MIT Roofnet [2], Berlin Roofnet [3]) as well as deployments in cities as a public service [4, 5] exist. Connections inside WMNs are automatically established over wireless links, which eases the deployment and reduces the costs. The mesh nodes build up an ad-hoc network over wireless links, which is adapted by the network's self-organisation capabilities. As all communication runs over wireless links, no wired backbone is required as for conventional access networks. These facts make WMNs easy to deploy and maintain.

Although WMNs provide increased network resilience due to self-organisation and redundancy in the network, the performance of real-time application suffers from quality variations of the wireless links. The noisy and erroneous wireless communication channel degenerates the quality of the real-time communication by bit errors or link failures. The bit errors in the data transmission require either additional redundancy or retransmissions and therefore reduce available bandwidth. Interference or other environmental changes may further cause link failures. High delays or packet loss are the consequence. The user received transmission quality becomes unacceptable due to high rate of artefacts, stumbles, or even interruptions. Hence the deployment of real-time applications in WMNs is challenging.

We propose to use path diversity and multi-stream coding to cope with the link quality variations in the network. The combination of both techniques may drastically reduce the effects of the wireless medium to the transmission. Multiple paths are usually not affected by the same errors, delays, jitter, and loss rates at the same time (see Figure 1 for an illustration). Their error characteristics are mostly uncorrelated. Therefore, the transmission over multiple paths (path diversity) adds redundancy and therewith lowers the influence of the unreliable wireless medium. The degree of redundancy can be optimised by using advanced multi-stream coding schemes such as layered (LC) or multi-description coding (MDC) [6, 7, 8]

instead of just sending the same stream multiple times. LC requires the correct reception of the base layer to reconstruct the input stream, whereas MDC can use any combination of received streams for reconstruction. The most appropriate encoding, coding parameters, and number of paths used for the transmission depend on the network conditions [9]. Therefore, the system has to dynamically adapt the parameter set, which consists of the encoding selection, the number of paths used, and the mapping of the individual streams to the paths.

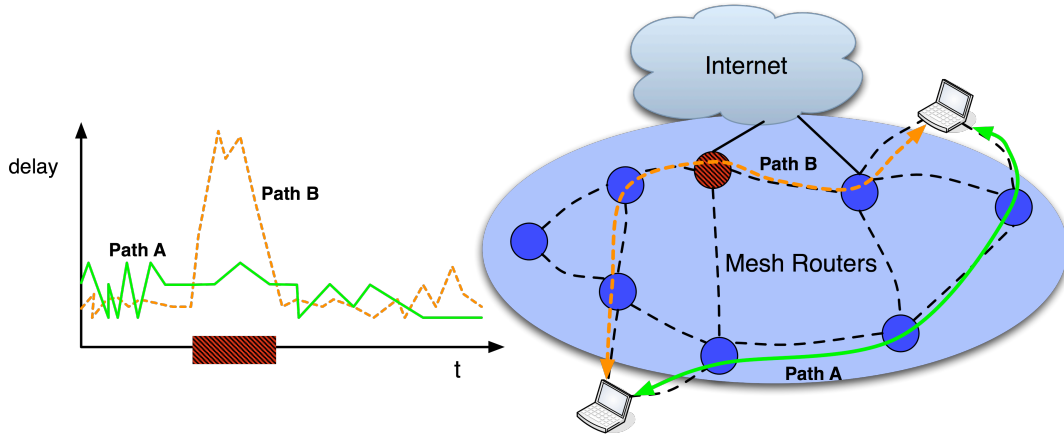


Figure 1: Delay Characteristics of Multiple Paths in the Network.

2. Adaptive Transport Over Multipaths (ATOM)

Adaptive transport over multipaths (ATOM) [10] provides support for real-time communication in WMNs. Path diversity and multi-stream coding are combined with dynamic adaptation to the current network conditions. ATOM uses the most appropriate selection of the paths provided by multi-path routing and multi-stream encoding options. It further maps the streams to the available paths. The decision-making process is supported by network measurements, monitoring, and statistical evaluation. It is further continuously repeated and therefore adapts to changes in the network conditions.

2.1 - ATOM Architecture

The general architecture of ATOM is shown in Figure 2. It consists of an ATOM aware application and the ATOM core components. The ATOM aware application implements the ATOM application-programming interface (API) in order to communicate with the ATOM core. It exchanges the available codec and coding options with the ATOM core and receives the configuration set (encoding, number of streams). In addition, it may provide feedback to the ATOM core during a communication session. The core then revises the decision and releases a new parameter set. The main functionality of ATOM is implemented in the ATOM core, which is split into the following components: ATOM controller, history and statistical analyser (HSA), monitoring and measurement system (MMS), multi-path routing, and path allocator. As the central component, the ATOM controller gathers control data and decides about the communication configuration used. It receives data about available encodings from the application(s), available paths from multi-path routing, the robustness of the path or individual links from HSA, and the current network conditions from MMS. Based on this data, it selects an optimised set of configuration parameters. The application is then requested to provide n streams with the selected encoding. The path allocator receives a map describing which stream has to be transmitted on which path. If necessary, the ATOM controller triggers a route discovery of new paths by multi-path routing. According to the feedback of the MMS and the application, it further revises its decision and adapts the transmission parameters.

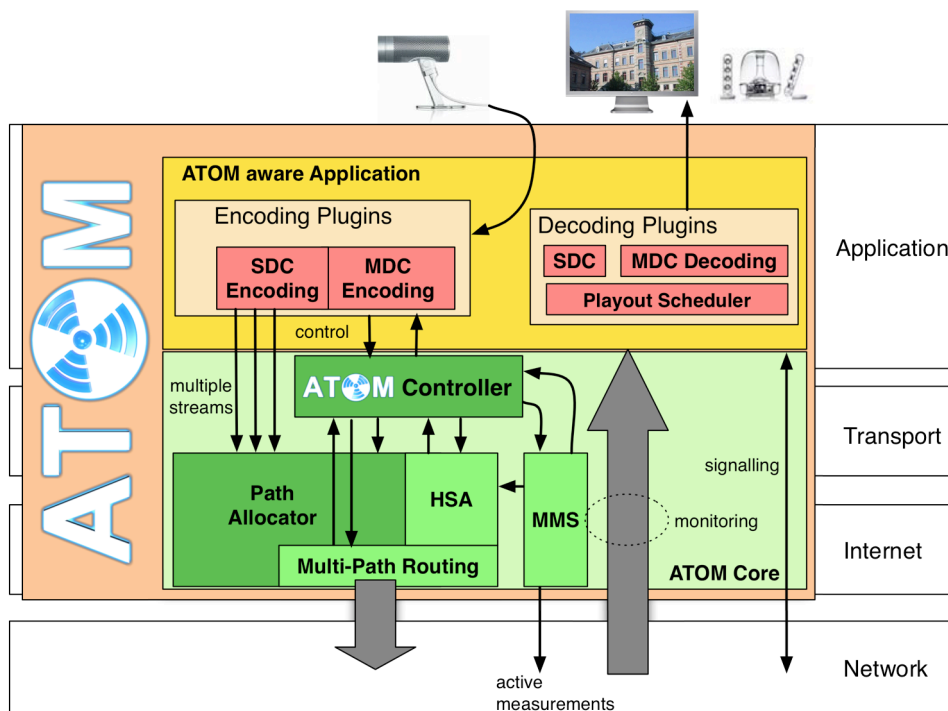


Figure 2: ATOM Architecture.

Besides the multi-path routing, which has to be installed in all mesh nodes, the ATOM core components can be placed at different locations inside WMNs (see Figure 3). Either all components are included in the end system or the core components are only situated in the mesh routers. The placement in the end system requires modifications in each end systems. ATOM core components have to be implemented for the different operating systems of the different end system devices. As second possibility, the ATOM core components can only be installed in the mesh nodes. This requires no further software installation at the client besides the ATOM aware application. Therefore, there is no need for porting the ATOM core to different operating systems. Only the mesh nodes, which typically run a Linux operating system, have to be supported. The control traffic between an ATOM-aware application and the ATOM controller then runs over TCP/IP. One drawback of the mesh placement is that the quality of the transmission strongly depends on the link quality between client and first mesh node. Furthermore, a combination of both approaches is possible.

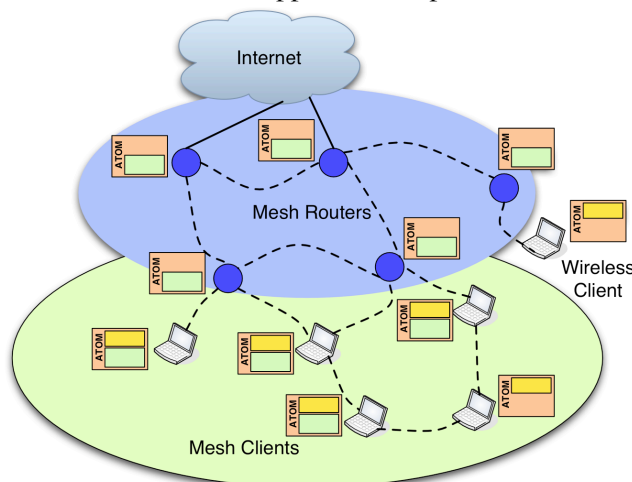
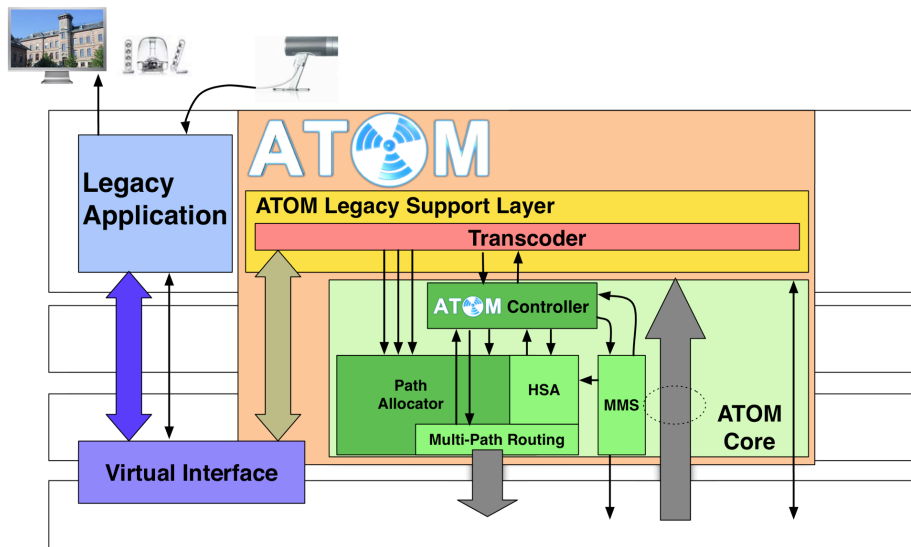
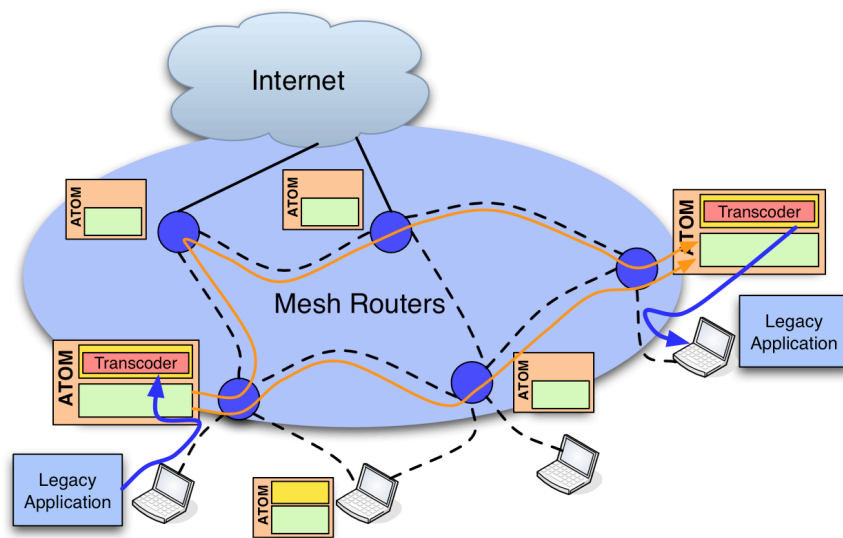


Figure 3: Placement of ATOM Components in the Wireless Mesh Network.

Moreover, the benefits of ATOM are offered to legacy applications. The two methods for ATOM legacy support are illustrated in Figure 4(a) and Figure 4(b). The first method provides the legacy support at the end system. The traffic of a legacy application is sent to a virtual interface, which forwards it to the ATOM legacy support layer. This layer establishes the ATOM session and transcodes the input stream to multiple streams. At the destination, the ATOM legacy support layer then merges the streams and forwards the output stream to the destination legacy layer. The second method puts the complete ATOM and transcoding functionality to the in- and outbound mesh routers.



(a) at the End Systems



(b) at In-/Outbound Mesh Routers

Figure 4: ATOM Support for Legacy Applications by Traffic Interception.

2.2 – Session Establishment and Release

ATOM has to establish a session before data communication can start and after communication has terminated it releases the session (see Figure 5). The lifetime of an ATOM session is divided into three phases:

- **Session establishment:** The ATOM-aware application at the source invites its communication peer and receives the available coding options. Then it requests an ATOM session at the ATOM controller. The request includes the mutually available coding options of both communication peers. The ATOM controller makes a decision based on the provided data including network state. It either accepts or denies the request. If the session is accepted, monitoring at the remote ATOM controller is started. The ACCEPT message includes the necessary parameters for the ATOM-aware application. The application then informs its remote peer about the acceptance of the requested session.
- **Data communication:** The ATOM-aware application transmits the streams to the destination.
- **Session release:** The ATOM-aware application closes the session by transmitting a CLOSE message. This message is acknowledged by a CLOSED message. After that, the application triggers the release of the session at the ATOM controller, which then stops the monitoring at the remote ATOM controller.

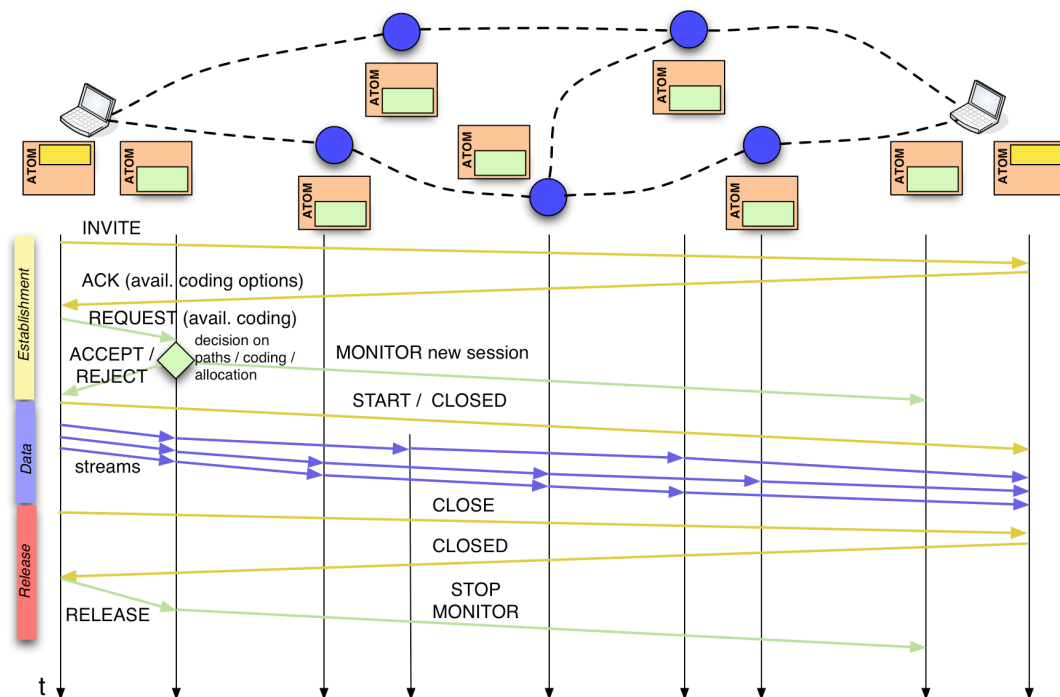


Figure 5: Session Establishment and Release.

2.3 – Session Reconfiguration: ATOM Adaptation Process

Changes in network conditions provoke an ATOM adaptation process during data communication (see Figure 6). If the remote ATOM controller or the (remote) application recognise a route break or high delays on one link, they inform the source ATOM controller through a NOTIFY message. The ATOM controller then revises its decision based on the new data. The new parameter set is sent to the source application and to the monitoring ATOM controller. Afterwards, the application informs its communication peer by a MODIFY message and then starts to transmit the streams according to the new parameter set.

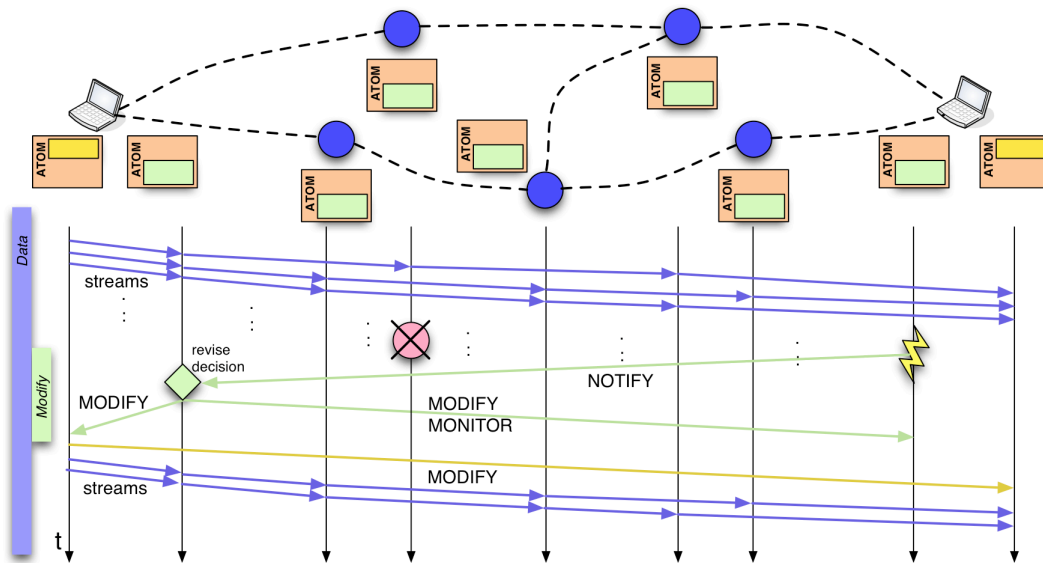


Figure 6: Session Reconfiguration.

3. Conclusion and Outlook

WMNs provide a reliable and robust communication infrastructure. But the erroneous nature of the wireless medium limits their usage as a network for real-time communication. ATOM solves this issue by combining multi-path routing, multi-stream coding, and dynamic adaptation. ATOM is work in progress. We are specifying the decision making process and the statistical analysis of the HSA. The ATOM components are currently being implemented in the network simulator Omnet++. Moreover, we are preparing the implementation of ATOM on our Linux based wireless mesh network testbed.

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References

- [1] I. F. Akyildiz and X. Wang, "A Survey on Wireless Mesh Networks," *Communications Magazine, IEEE*, vol. 43, no. 9, pp. 23–30, 2005.
- [2] J. C. Bicket, D. Aguayo, S. Biswas, and R. Morris, "Architecture and Evaluation of an Unplanned 802.11b Mesh Network.," in *11th Annual International Conference on Mobile Computing and Networking (MOBICOM 2005)*, (Cologne, Germany), pp. 31–42, Aug. 28 – Sept. 2 2005.
- [3] R. Sombrutzki, A. Zubow, M. Kurth, and J.-P. Redlich, "Self-Organization in Community Mesh Networks the Berlin Roofnet," *1st Workshop on Operator-Assisted (Wireless Mesh) Community Networks*, pp. 1–11, Sept. 2006.
- [4] R. Karrer, A. Sabharwal, and E. Knightly, "Enabling Large-Scale Wireless Broadband: The Case for Taps.," in *2nd Workshop on Hot Topics in Networks (Hot-Nets II)*, (Cambridge, USA), Nov. 2003.
- [5] "Meraki 'free the net' Project in San Francisco" online: <http://meraki.com/about/freethenet/>, 2007.
- [6] J. G. Apostolopoulos and M. D. Trott, "Path Diversity for Enhanced Media Streaming," *IEEE Communications Magazine*, vol. 42, pp. 80–87, Aug. 2004.
- [7] Y. J. Liang, E. G. Steinbach, and B. Girod, "Real-Time Voice Communication Over the Internet Using Packet Path Diversity," in *MULTIMEDIA '01: Proceedings of the ninth ACM international conference on Multimedia*, (Ottawa, Canada), pp. 431–440, ACM Press, 2001.
- [8] N. Gogate, D.-M. Chung, S. Panwar, and Y. Wang, "Supporting Image and Video Applications in a Multi-Hop Radio Environment Using Path Diversity and Multiple Description Coding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 12, pp. 777–792, Sept. 2002.
- [9] J. Chakareski, S. Han, and B. Girod, "Layered Coding vs. Multiple Descriptions for Video Streaming Over Multiple Paths," *Multimedia Systems*, vol. 10, pp. 275–285, April 2005.
- [10] T. Staub and T. Braun, "ATOM: Adaptive Transport over Multipaths in Wireless Mesh Networks," *2nd ERCIM Workshop on eMobility*, (Tampere, Finland), May 30 2008.