Adaptive Quality of Service (AQoS)

Aim/Purpose/Objective

In a tactical environment network resources are often insufficient and cannot meet demand. Consequently, bandwidth allocation to support diverse missions is an important and ongoing problem. Wireless networks such as mesh networks or MANETs are particularly challenging because the available bandwidth can vary widely and unpredictably. The technical problems to be addressed are

1. Network bandwidth must be reallocated quickly and repeatedly, but must continue to maximize contributions to mission success.
2. Applications that consume bandwidth should be able to provide lower quality but still useful service as network resources become increasingly scarce.
3. Techniques that estimate and predict as a basis for adaptation do not work in this setting.

The final goal of this work is to provide autonomous online adaptation of application demand in a way that (a) meets local needs and (b) maximizes global utility.

Related Work

Much related work either tries to predict resource exhaustion based on resource usage and availability estimates, or tries to provide mechanisms that are transparent to applications. In contrast, AQoS is reactive and requires applications to adapt to sensed network state. AQoS builds upon the Q-RAM approach to manage bandwidth allocation.

[Carvalho 2006] M. Carvalho, N. Suri, V. Shurbanov, E. Lloyd, A Cross-layer Network Substrate for the Battlefield, in Proceedings of the 25th Army Science Conference, Orlando, FL, USA, 2006.

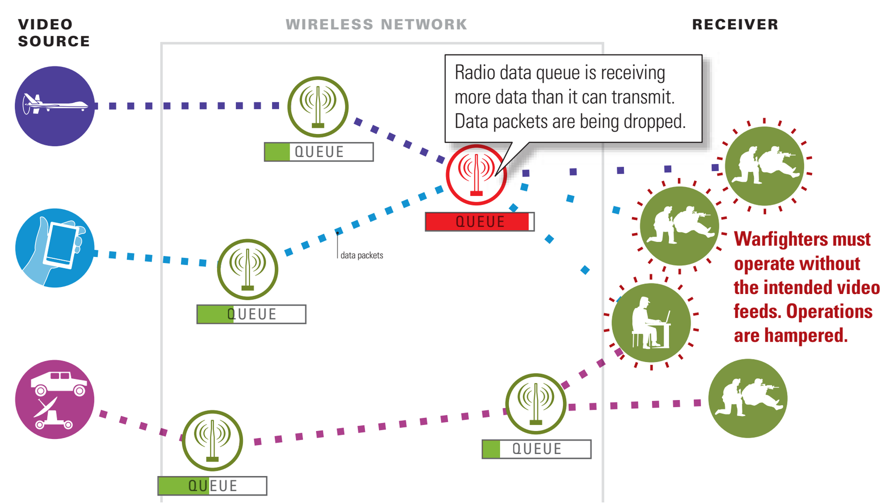
[Hoover 2002] Hoover, C., Hansen, J., Koopman, P. & Tamboli, S. "The Amaranth Framework: Policy-Based Quality of Service Management for High Assurance Computing." International Journal of Reliability,Quality and Safety Engineering 8, 4 (December 2001): 323-350

[Lee 1999] Lee, C., Lehoczky, J., Rajkumar, R. & Hansen, J. "A Scalable Solution to the Multi-Resource QoS Problem," 315-326. Proceedings of the 20th IEEE Real-Time Systems Symposium. Phoenix, AZ (USA), December 1999. IEEE, 1999.

[Loyalla 2009] J. Loyall, M. Carvalho, A. Martignoni III, D. Schmidt, A. Sinclair, M. Gillen, J. Edmondson, L. Bunch, D. Corman, "QoS Enabled Dissemination of Managed Information Objects in a Publish-Subscribe-Query Information Broker," SPIE Conference on Defense Transformation and Net-Centric Systems, April 13-17, 2009.

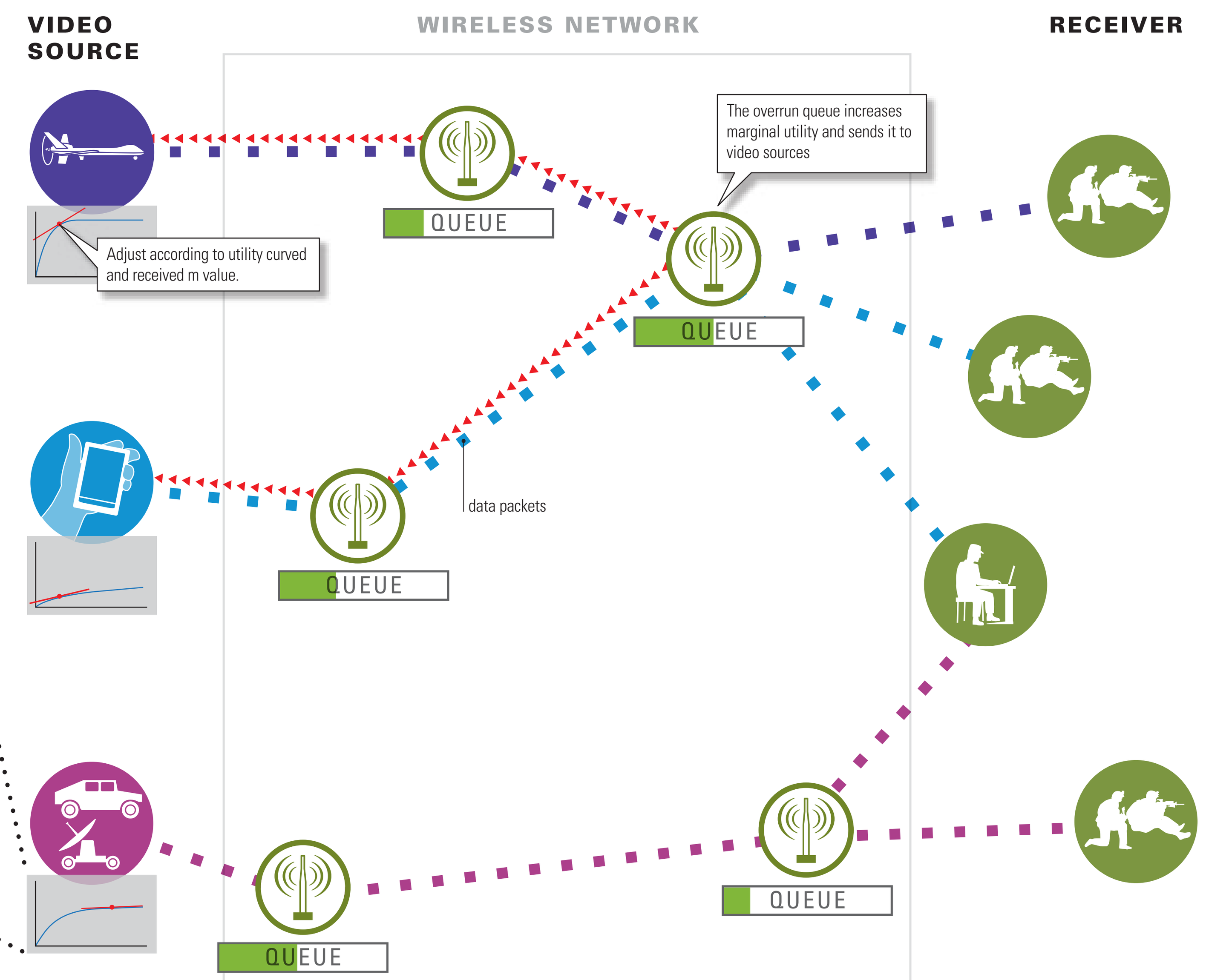
PROBLEM

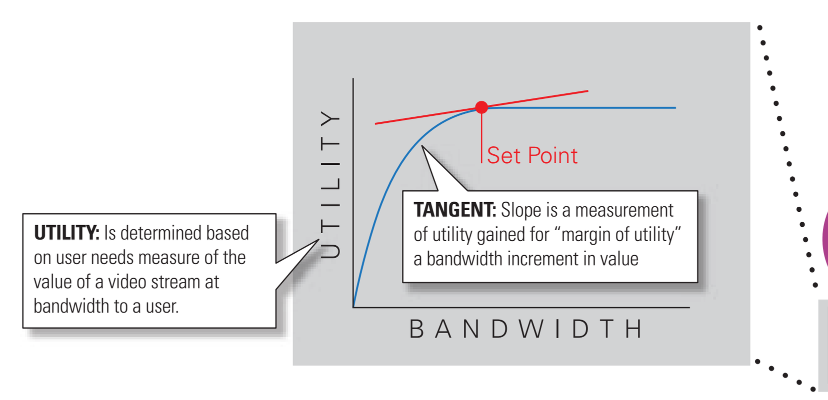
A radio is dropping data packets because of a weak connection.



DISTRIBUTED Q-RAM SOLUTION

All video sources have their bandwidth adjusted to a sustainable level of transmission.





Other Work, continued

[Oh 2010] Oh, S., Marfia, G., & Gerla, M. "MANET QoS Support without Reservations." Security and Communication Networks. Wiley Interscience Online (www.interscience.wiley.com). DOI: 10.1002/sec.183, 2010.

[Tortonesi 2006] Tortonesi, M., Stefanelli, C., Suri, N., Arguedas, M., and Breedy, M., "Mockets: a novel message-oriented communication middleware for the wireless internet," Proc. Int. Conf. on Wireless Information Networks and Systems (WINSYS 2006), Setúbal, Portugal, 2006.

The Design of this Experiment

AQoS builds on the following assumptions.

- Applications are provided information enabling them to adapt in response to indicators of insufficient network capacity.
- The networking infrastructure does not need knowledge of the applications' data semantics (e.g., voice or video).
- The network infrastructure does not need to reserve or predict available capacity.

In a MANET an AQoS module is installed on every wireless router that participates in the network. The module tracks which data flows pass though the router and observes the router's outgoing queue length. When network capacity is insufficient, the queue fills up, and if enough capacity is available, the queues empty. The AQoS module sends periodic messages to data sources to allow them to adjust data rates accordingly.

Experiment Design, continued

Our approach, distributed Q-RAM supports global utility optimization without the need for a central server that calculates application QoS set points. Each router maintains a local marginal utility value (m-value). If the queue fills up, the m-value increased and vice versa. This m-value is communicated to the data sources. Each data source application maintains a local utility profile that associates a utility value with consumed bandwidth. Whenever the application receives a new m-value, it calculates a point on its (concave) utility curve where the derivative (slope of the tangent) matches this m-value. This point identifies a set point for the data rate on the x-axis and a utility on the y-axis. If all applications follow this process, the resulting bandwidth allocation will be close to optimal.

The utility-based approach can also be used to incorporate the relative importance of data flows into the bandwidth allocation. Each data flow is assigned a relative weight and the utility curve of each flow is multiplied by the weight.

We measure the quality of a data flow by delivered utility per time unit. The quality score is calculated as the time average of the sum of the utilities of all data received:

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where is the time interval over which the score was measured, is the number of flows, is the number of frames received for Flow , and , is the utility at the sender's set point.

Results

We tested AQoS by transmitting several video streams over a wireless mesh network. Our results show that AQoS is able to keep a video stream of high importance at a higher quality than low importance streams if the network bandwidth degrades.

Also, AQoS shows a huge increase in combined delivered utility for the video streams over multi-hop connections. In unmanaged routers the delivered utility drops sharply for more than two hops, whereas AQoS managed routers can deliver video streams over up to 6 hops.

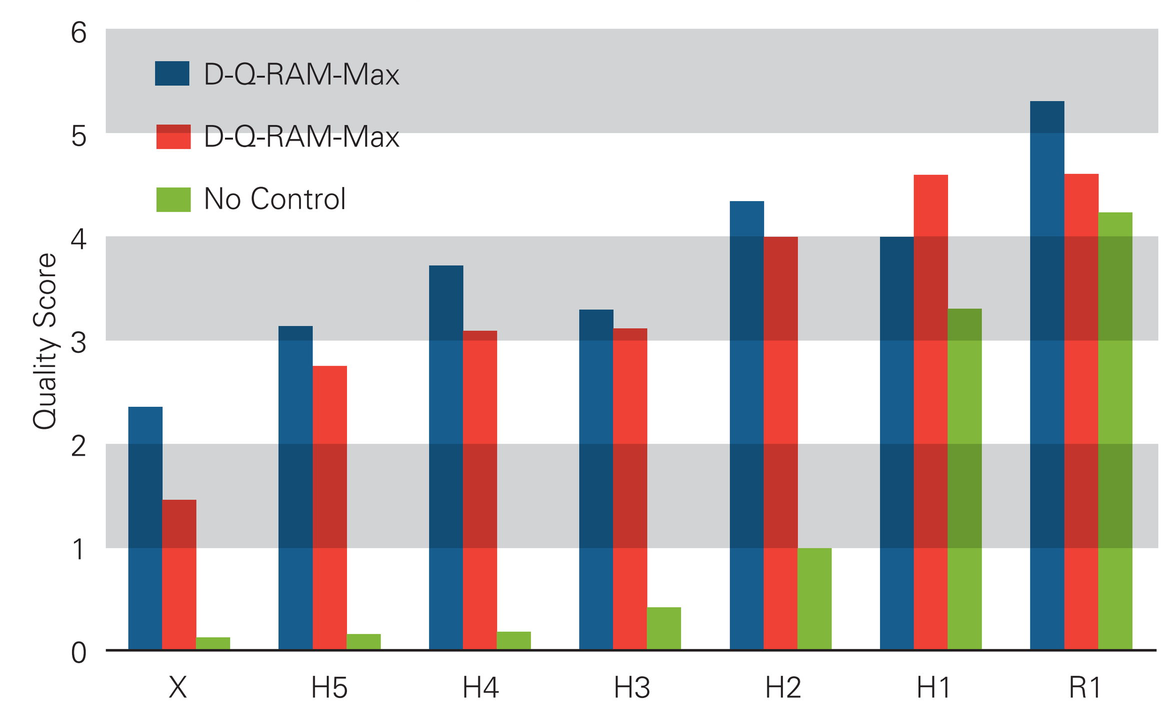

Figure 8: Comparison of Quality Scores for D-Q-RAM versus No Control

Results from an earlier, priority based, approach to AQoS are published as an SEI technical report (TR XXX-2010)

Considerations and Next Steps

Current results are based on experiments with a real mesh network. We are creating simulation capability that allows to experiment with variations of parameter settings comparatively quickly. We will use the existing and new experimental data to calibrate the simulation.

In a mesh network multiple routers can become congested at the same time and send updated m-values to a data source. These m-values must be consolidated into a single set point. We will conduct experiments to determine how this can be done to maximize utility.

Further into the future, we plan to include latency as another dimension into utility assessment and bandwidth allocation decision.

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