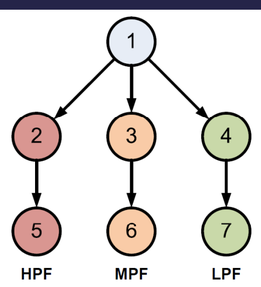
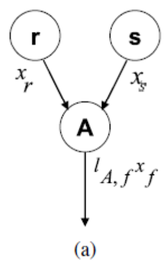
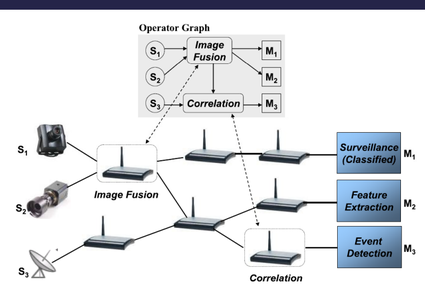
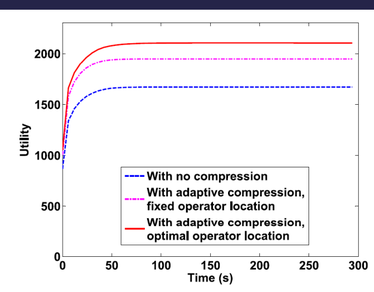
Adaptive In-Network Processing for Mission-Aware WSNs

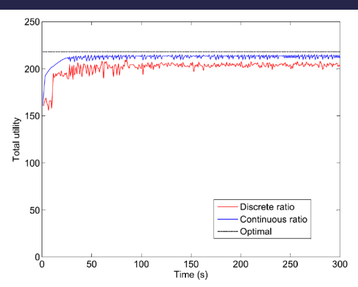
Sharanya Eswaran, James Edwards, Thomas La Porta











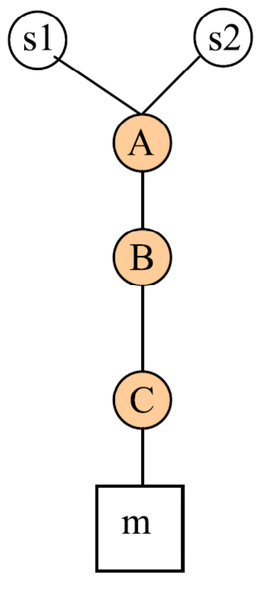
Protocol Background

•The Adapative In-Network Processing Framework (NUM-INP) allows nodes within a network to compress or fuse sensor data in a dynamic condition-based manner.

•Extends from previous work on Wireless Network Utility Optimization, a provably optimal framework that generates a closed-form solution to network resource allocation.

•The utility of sensor data, along with network conditions determine the level of stream compression, allowing prioritization of flows within a network.

•The expected values of rate and utility obtained through simulation are confirmed through implementation on wireless laptops streaming video samples.



•**Optimization Framework:**

NUM-INP(U,C,P):

$$\max \sum_{m \in M} U_m(\{x_s^{rec}\}_{s \in sset(m)}) - \delta \sum_{\forall nodes,k} P_{tot}^k \quad (2)$$

subject to

i)**Capacity Constraint:**

$$\sum_{\forall (k,i) \in q} \frac{x_{out}(i,k)}{c_{ki}} \leq 1, \forall q \in set\ of\ cliques,\ Q \quad (3)$$

ii)**Energy Constraint:**

$$P_{tot}^k \leq P_{max}^k, \forall nodes, k \quad (4)$$

where $P_{tot}^k = P_{rec}^k + P_{trans}^k + P_{comp}^k$, $0 \leq \delta \leq 1$ **and** $x_i,\ x_{out}(i,k) \geq 0\ \forall i,k$

Implementation Architecture

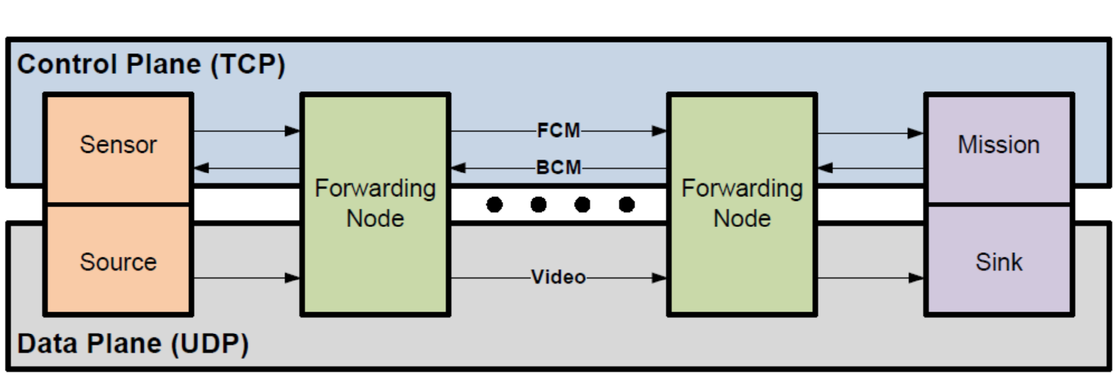
•Implementation of protocol on 7 computers with wireless network interfaces configured in an ad-hoc network using Linux and VLC for streaming video.

•Nodes classified into three groups:

- •Sensor / Source – Initial generator of data stream
- •Forwarding Nodes – Process data as necessary and forward downstream
- •Mission / Sink – Updates the source / sensor with the value of the data

•Control Plane

- •Forward Control Messages (Source to Sink)
  - •Updated downstream nodes of rate information
- •Backward Control Messages (Sink to Source)
  - •Updated upstream nodes of sensor data utility (value), downstream node conditions (power) and network conditions (interference).
  - •Poor downstream network conditions might cause forwarding nodes to compress data



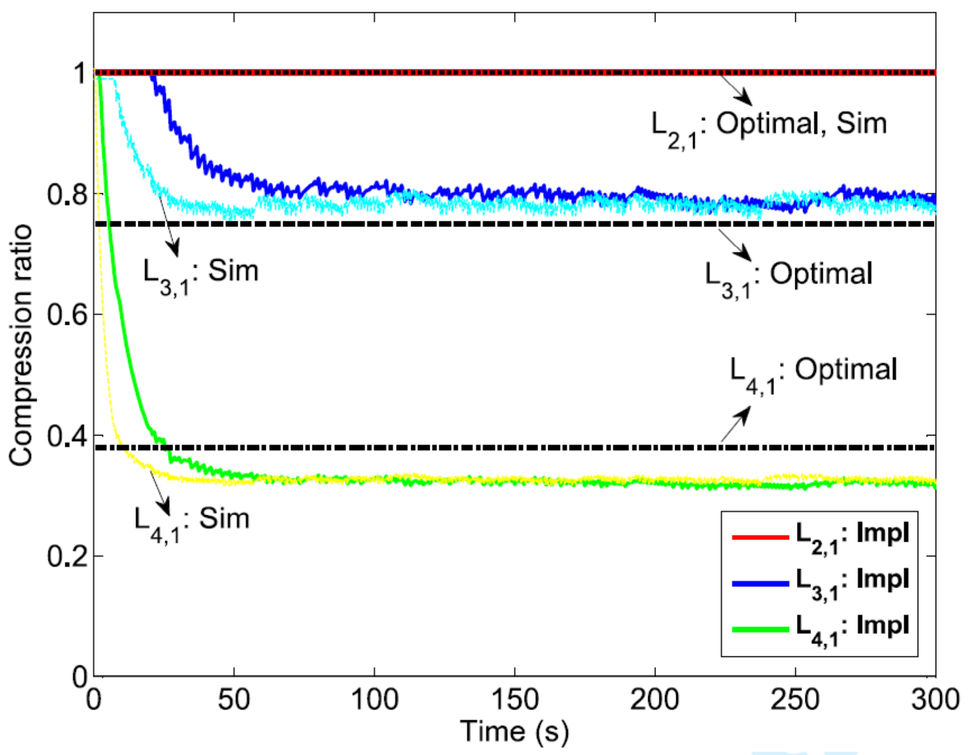
•Video samples were continuously streamed point-to-point over UDP.

•Our implementation tested prioritized flows with and without the in-network processing protocol. Screenshots of the received video are shown at the right.

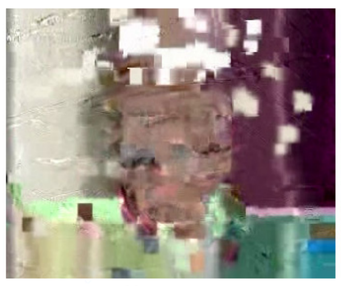
•We showed that use of the NUM-INP protocol *increased* our packet delivery ratio of our sensor data as well as the video quality at the sinks while *simultaneously decreasing* the amount of power consumed.

•With a control plane update rate of 1 update / 3 seconds, we saw transmission rate and compression ratio convergence in less than sixty seconds.

Results



	Without NUM-INP	With NUM-INP
PDR (%)	81.83	93.36
Power (W)	38.38	32.45
Video Quality (PSNR)		
Mission 5 (HPF)	14.86	98.12
Mission 6 (MPF)	15.03	45.86
Mission 7 (LPF)	0	29.15



(a) At M_1 without adaptation

(c) At M_2 without adaptation

(e) At M_3 without adaptation

(b) At M_1 with adaptation

(d) At M_2 with adaptation

(f) At M_3 with adaptation

SPONSORED BY THE US-ARL INTERNATIONAL TECHNOLOGY ALLIANCE