



Meerkats: A Power--Aware, Self--Managing Wireless Camera Network for Wide Area Monitoring

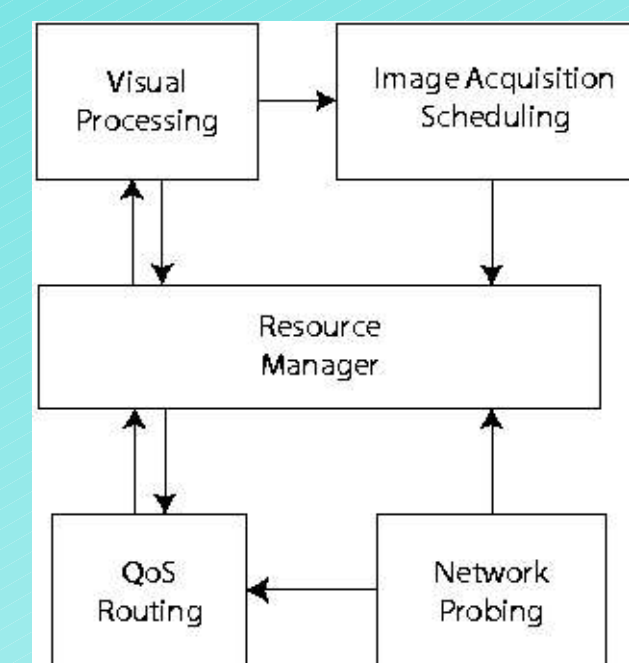
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What is Meerkats?

- Wireless network of battery-operated camera nodes for monitoring and surveillance of wide areas.
- Integrates visual sensing and processing with network-level techniques for adequate QoS delivery

System Architecture



Visual Processing (VP) module:

- Responsible for detecting and characterizing events within a camera's field of view (FOV).
- Performs collaborative sensor processing: information from multiple cameras is fused for more accurate event detection.

Image Acquisition Scheduling (IAS) module:

- Determines the miss rate as a function of the allocated number of snapshots together with the optimal snapshot times.
- Uses information from the VP module (which may contain the currently estimated location, direction and velocity of motion of a tracked target).

QoS Routing module:

- Performs discovery and maintenance of routes that are able to meet the quality-of-service (QoS) requirements of the application in a power-efficient way.
- Needs information on the network's current conditions (e.g., bandwidth, delay), as well as remaining power in the nodes.

Network Probing module:

- Provides information on bandwidth and delay estimates, and remaining battery for neighboring nodes to the QoS-routing module.

Resource Manager (RM):

- Receives information from all modules and makes system-wide information management decisions.
- Considers input from nearby nodes.
- Decides when to activate a camera based on information about actual- versus required miss rate and available power.
- Integrates information from the IAS module (e.g., miss rate as a function of snapshots, optimal snapshot times, etc.) with any other available information to task camera nodes that are most likely to see the target next.
- Accounts for power consumed by the various tasks involved (e.g., processing sensing, communication).
- Decides which data representation level should be employed for visual data transmission given the available bandwidth and power at a given node.
- Advises QoS routing on which metric to use when selecting routes.

Testbed:

- Network with 8 Crossbow Stargate boards:
- XScale PXA255 CPU (400MHz)
 - 32M flash, 64M DRAM
 - Running Stargate v. 7.3 (embedded Linux)
 - Orinoco Gold 802.11b wireless PC card
 - QuickCam Pro 4000 camera (USB port)
 - Custom 2-cell Li-Ion 7.4 Volt, 1 Ah battery

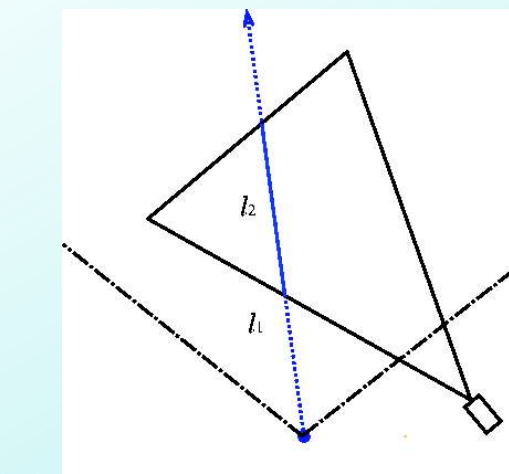


IAS - Miss rate Analysis:

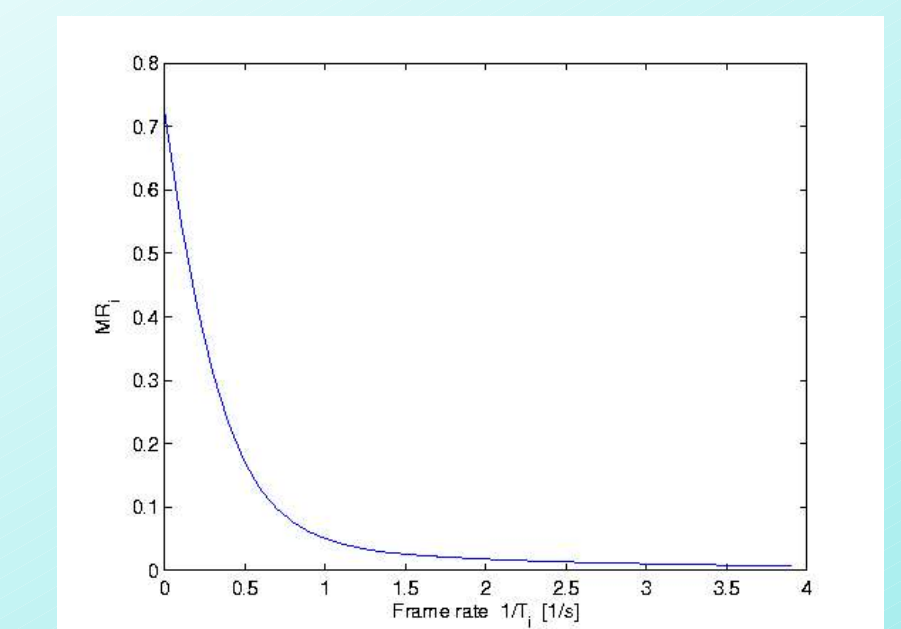
End Node:

$$P_{M|F} = \int \int_{f|F} p_f(f) p_v(v) \left(1 - \frac{\min(l_2(f)/l_v, T_i)}{T_i} \right) dv df$$

- X = moving body in network area
- F = body enters camera's FOV
- M_i = miss from camera i
- p_v = velocity distribution
- p_θ = angle distribution
- T_i = frame period
- Miss Rate $MR_i = P_{M|F} P_{F|X}$



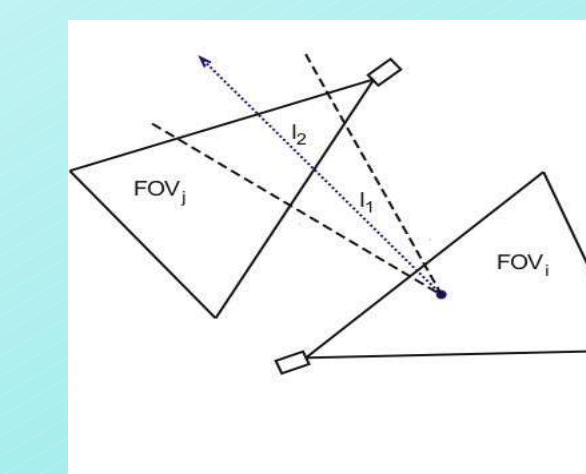
(a): A possible layout of an end node. The triangular shape represents the node's FOV, while the angular sector represents the possible direction of motion.



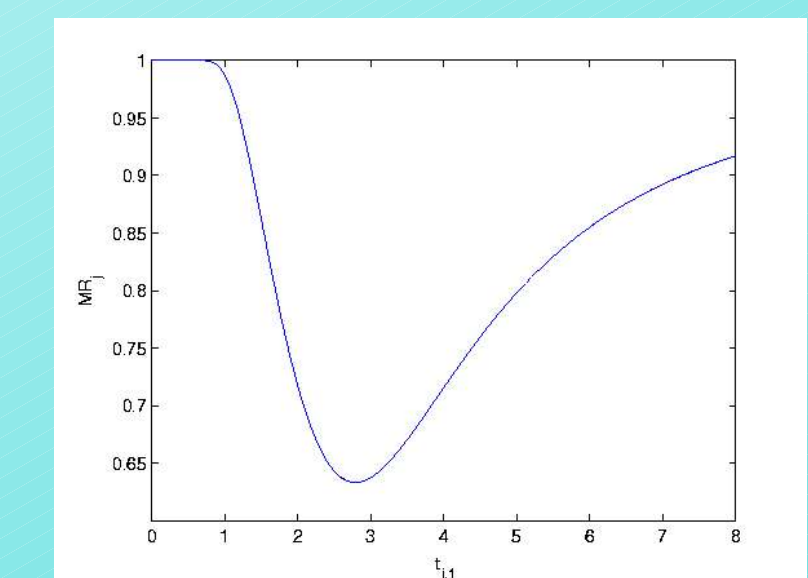
(b): The miss rate as a function of the snapshot rate (1/Ti) for an end node.

Internal Node:

$$P_{M|F} = \int_{f|F} p_f(f) \left(1 - \frac{l_1(f) + l_2(f)}{l_1 - l_0} \int_{l_1(f)}^{l_2(f)} p_v(v) dv \right) df$$



(a): A possible layout of an internal node. An event has been detected at time $t(0)$ by another sensor, which estimated that a body is moving within the specified angular sector.



(b): The miss rate as a function of the time $t(j,1)$ at which a single snapshot is taken by the camera.

VP- Motion Detection:



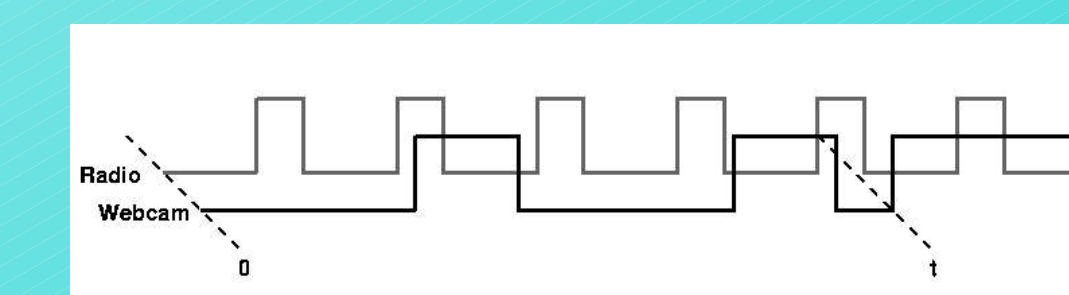
(a): A frame of a sequence with a moving person.



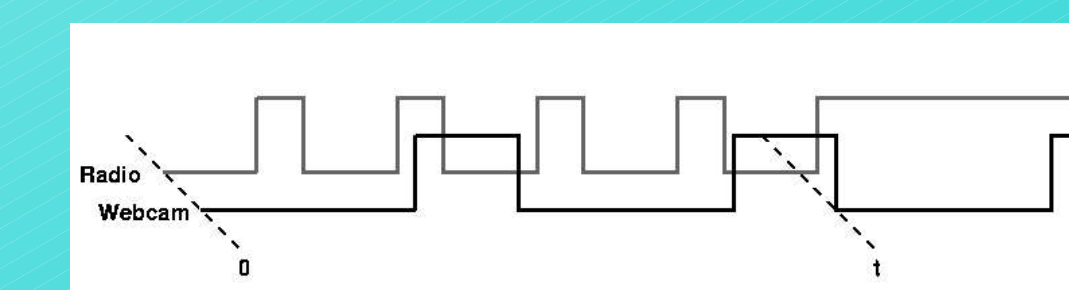
(b): Motion labeling. White: no motion; Gray: motion; Black: outlier.

Synchronization Issues:

Ideally, nodes (both radio and camera) should sleep whenever there is no activity.



(a): At time t , radio receives a "camera wake-up" message from neighbor. Stargate turns on webcam and begins taking pictures.



(b): At time t , camera sees object of interest. During next radio period, node sends 'wake-up' to neighbors and transmits image to sink.