Adaptive Control Management for Ubiquitous Service with Sensor Actuator Network

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☐ Background
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Ubiquitous Service

- Because of the lag between cost paying phase and utility gaining phase in the activity, and the variation of amount of utility gained among cost paying units, mechanisms that calm and hopefully enhance the activity environment have been developed.

- Ubiquitous service can increase utilities thru the virtuous circle.
Ubiquitous Service

Production activities

Feedback mechanisms

\[ x_i(k) \rightarrow p_i(k) \]

\[ x_i(k+1) \rightarrow p_i(k+1) \]
Ubiquitous Service

☐ Public or Private?

☐ So long as economies of scale works, the utility providing activity would be done in public manner.

☐ Even though the provision of utility is only for private use, it can be public if it creates the negative externality.
Cost for Ubiquitous Service

- Utilities require various costs (monetary/energy/environment) in several stages to be served.
  - Initial Cost
  - Maintenance Cost
  - Unit Cost
  - Delivery Cost (Storage/Division)
  - Optimization Cost (Inspection/Calculation)
- Marginal Cost = Unit Cost + Delivery Cost
- Running Cost
Utility of Ubiquitous Service

- Served utilities are realized in several ways (monetary/service realization).

- Concentrated utilities may diminish (the law of diminishing returns). Dispersed ones may be more desirable in such cases.

- Or concentrated utilities may produce synergy (e.g. network externality effect, bandwagon effect, threshold). Costs for the provision of same amount of utilities may be saved in such cases.

- A series or a combination of homo/heterogeneous utilities can comprise a certain service utility.
Inspection

- Measurement of monetary / energy cost
- Measurement of environmental cost
  - Spatial and temporal resource consumption
- Measurement of emerging utility
  - Spread of served utility
    - Service (e.g. contents, observability, controllability)
- Investigation of QoS requirement for utilities
Goal: Service Dynamism

- Designing the mechanism where sensors and actuators negotiate the exchange of cost and utility to fulfill the user's satisfaction.
- And also, analysis of cost utility structure by using limited information is to be achieved.
- And also, updating the cost utility structure that changes from a situation to another situation.
- Runtime mechanism designer governs the service distributors by giving incentives and taxing.
Case (Topocasting)

- A video camera distributes video data by casting a radio signal steered for the same direction as the camera takes video.
- The radio signal conveys broadcast packets in the broadcasting way to the devices held by the users who are in the area where the radio signal is demodulated.
- The broadcast packets are multiplexed among the neighboring video cameras (and other devices) temporally and spatially.
Frame Coverage

Wireless Camera

Frame Coverage

10m

100m
Radio Propagation

\[ P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \]

\[ P_{rt_f}(50) = \frac{P_t G_{tf} G_r \lambda^2}{(4\pi)^2 50^2 L} [mW] = 10^{-6} [mW] = -60 [dBm] \]

\[ P_{rt_b}(d) = 6.25 \cdot 10^{-4} \cdot \frac{1}{d^2} [mW] \]

\[ = -32.0 - 20 \log_{10} d [dBm] \]
Mixture of 2 Cameras

\[
K_1 : \begin{cases} 
\frac{P_{rt_b}(u-k_1)}{P_{rt_b}(u-k_2)+P_{rn}} \\
\frac{P_{rt_f}(u-k_1)}{P_{rt_f}(u-k_2)+P_{rn}} \\
\frac{P_{rt_f}(u-k_1)}{P_{rt_f}(u-k_2)+P_{rn}}
\end{cases} \quad \geq 10 \quad K_2 : \begin{cases} 
\frac{P_{rt_b}(u-k_2)}{P_{rt_b}(u-k_1)+P_{rn}} \\
\frac{P_{rt_f}(u-k_2)}{P_{rt_f}(u-k_1)+P_{rn}} \\
\frac{P_{rt_f}(u-k_2)}{P_{rt_f}(u-k_1)+P_{rn}}
\end{cases} \quad \geq 10 \quad (u < k_1) \quad (k_1 < u < k_2) \quad (k_2 < u)
\]

Wireless Camera

30m

User device

30m

100m

K_1

K_2
Mixture of 2 Cameras

Wireless Camera

30m $K_1$

30m $K_2$

100m

User device
Mixture of 2-4 Cameras
Mixture of 10 Cameras
10 Cameras for Full Frame Coverage
Sets for Full Coverage

- Using the result of inspection, some calculations are executed and the procedure of utility distribution is specified.

- And also, the procedure of inspection can be updated.
Inspection & Calculation

- Measurement of the signal propagation area from service nodes, and consequently, spatial and temporal resource consumption
- Inspection of the service coverage of service nodes
- Designing the optimized procedure of optimized assignment of resource consumption for service nodes to serve utilities.
- Designing the optimized procedure of investigation of the realization extent of service utilities (quality of content delivery, observability and controllability)
Crossing Street

Wireless Camera

Frame Coverage

50m

100m
Panoramic Camera

Wireless Panoramic Camera

Frame Coverage

50m

10m

50m

100m
Covering 2-dim. Area

Wireless Panoramic Camera

Frame Coverage

10m
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