# Video Streaming and Transmission scheduling in Wireless Networks


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## Video streaming over Multiple wireless interfaces

### Overview:

Multiple wireless interfaces are integrated with the latest portable devices:

Bluetooth

WiFi

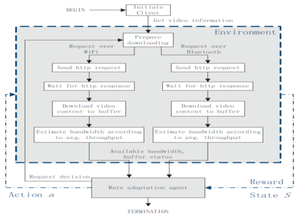
Lte

### Benefits:

Why we need to utilize multiple interfaces?

- The aggregated higher bandwidth can support video of higher bit rate
- When one wireless link suffers poor link quality or congestion, the other one can compensate it

### System model & Problem formulation



The streaming process can be modeled with Reinforcement learning process, we define a state $S_n$ for each step:

$S_n = (q_n, \Delta q_n, v_n, \Delta v_n, t_n, \Delta t_n, bw_n, bg_n, d_n)$

Actions and related rewards

Actions: maintain, increase or decrease one layer

| State $s_t = s$ | Reward $R(s)$ |
|---|---|
| $(*,*,*,*,*,*,*,*,N_T)$ | 0 |
| $(q,*,*,*,*,*,*,*,*)$, if $q < T_{qmin}$ | $-(Q_L - q) + \Delta q$ |
| $(q,*,*,*,*,*,*,*,*)$, if $q > T_{qmax}$ | $-q - \Delta q$ |
| $(*,\Delta q,*,\Delta v,t,\Delta t,*,*)$ | $\min(-\lvert\Delta v\rvert, -\lvert\Delta q\rvert) - \Delta t R_t$ |
| other states | 0 |
| any state with smooth action | $R_s$ |

Finally, we model the problem as a Markov decision problem (MDP), the objective is to find the optimal strategy policy $\pi$:

$$\pi^*(s) = \arg\max_{\pi} \sum_{s'} \mathcal{P}^a_{ss'}[R^a(s) + \gamma V^*(s')]$$

### Adaptive streaming algorithm design

Bandwidth Estimation with Homogeneous Markov chain model, the transition matrix is updated after each step

$$p_{ij} = \frac{c_{ij} + 1}{\sum_{j=1}^{n} c_{ij} + n}$$

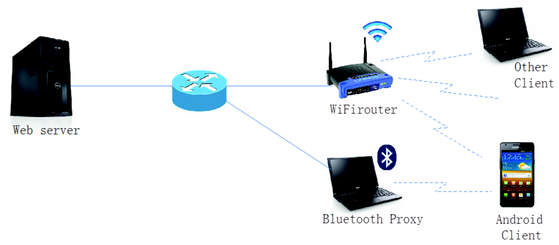
Real-time searching algorithm

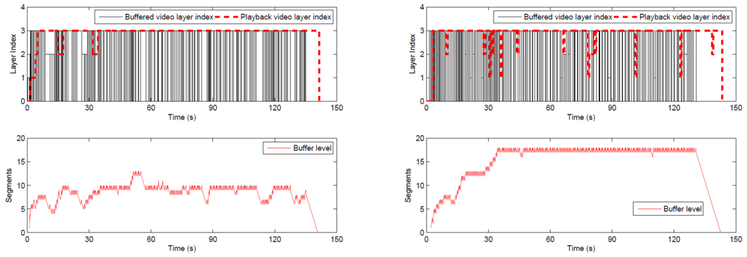
**Algorithm 1** Real-Time Best-Action Search Algorithm

```
procedure GETBESTACTION(s)
    Initialize action ← −1, Q_max ← −∞
    Generate all possible actions A(s) for state s
    for all Action a ∈ A(s) do
        q ← REWARDSEARCH(s, a, 0)
        if q > Q_max then
            Q_max ← q, action ← a
        end if
    end for
    return action
end procedure

procedure REWARDSEARCH(s, a, d)
    q ← reward of (s,a)
    if d ≥ D then
        return q
    end if
    Generate all possible next states S′ of (s,a)
    for all s′ from S′ do
        Q_max ← −∞
        Generate all possible actions A′(s) for state s′
        for all Action a′ ∈ A′(s) do
            Q_t ← REWARDSEARCH(s′, a′, d + 1)
            if Q_t > Q_max then
                Q_max ← Q_t
            end if
        end for
        q ← q + γP_ss′Q_max
    end for
    return q
end procedure
```

### Experiment settings and results:



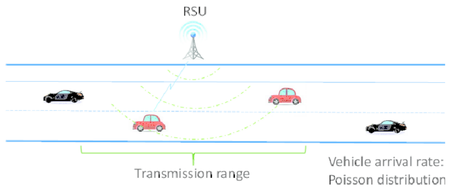

(a) RTRA (b) KERA

## Video transmission scheduling in Drive-thru Internet

### Overview:

Multimedia data transmission can improve the passengers' travel experience in Drive-thru Internet.

It can also enhance the road safety.

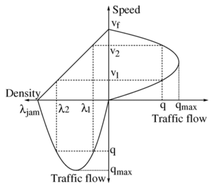



### Challenges:

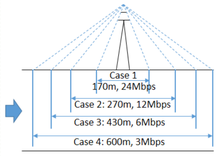
- Due to mobility, the sojourn time of each vehicle in the RSU's coverage range is limited, which restricts the total amount of data that can be transmitted
- Since there are multiple vehicles competing for the limited bandwidths, the throughput of each vehicle will be further reduced.

### System model & Problem formulation

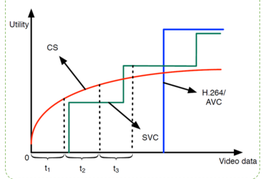
Traffic model: Poisson arrival rate



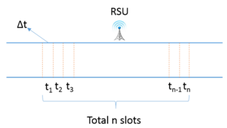

Wireless model: Divide the coverage into several regions




Utility model: Map the throughput to satisfactory level




Problem formulation




$$\text{UMP: max} \sum_{i=1}^{N_c} U_i + \sum_{n=1}^{T} \mathbf{E}(U_n),$$

$$\text{s.t. } a_k(t) \in \{0,1\}, k = 1, 2, \ldots N_T,$$

$$\sum_{l=1}^{N_T} a_l(t) \le 1,$$

The utility for current vehicles in the RSU's coverage range

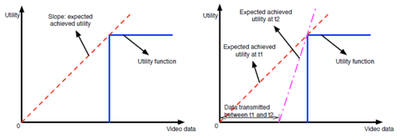
Expected utility for future arrival vehicles

### Algorithm design

Utility potential: the total amount of utility can be obtained during the next $n$ slots over $n$

$$n_s = \frac{2R - P_i}{v_i \Delta t} \qquad U_n = \frac{F_u^i(\sum_{i=1}^{n} w_i \Delta t)}{n}$$

Finding the maximum utility potential for all vehicles currently in the RSU's coverage range, and choose the vehicle with the highest utility potential to transmit

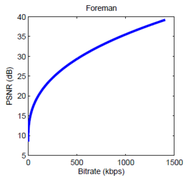


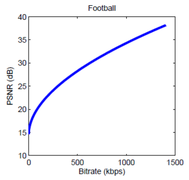

(a) Utility Potential at time $t_0$ (b) Utility Potential at time $t_1$

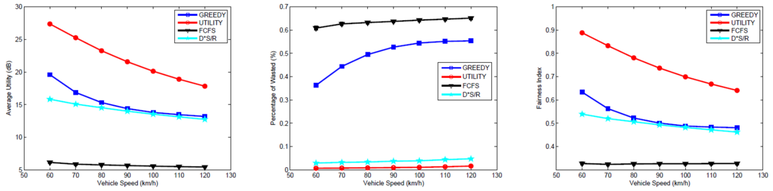
### Simulation settings and results:

VIDEO ENCODING CONFIGURATIONS

| Video | Codec | Avg. Bitrate | Avg. PSNR |
|---|---|---|---|
| Foreman | H.264 | 726.8 kbps | 39.5 dB |
| | SVC layer 1 | 98.6 kbps | 29.2 dB |
| | SVC layer 2 | 158 kbps | 32.89 dB |
| | SVC layer 3 | 374 kbps | 36.8 dB |
| | CS | Avg. PSNR $\approx 2 \times \text{Bitrate}^{0.38} + 8.51$ | |
| Football | H.264 | 603.31 kbps | 33.75 dB |
| | SVC layer 1 | 537.9 kbps | 29.16 dB |
| | SVC layer 2 | 958.2 kbps | 33.27 dB |
| | SVC layer 3 | 1408.7 kbps | 35.53 dB |
| | CS | Avg. PSNR $\approx 0.51 \times \text{Bitrate}^{0.53} + 14.62$ | |




(a) Utility. (b) Percentage of Wasted Throughput. (c) Fairness Index.

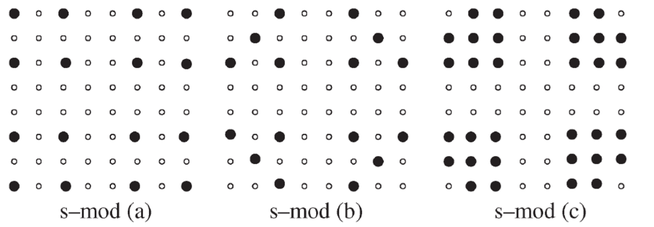
## Video streaming with scalable modulation Demo

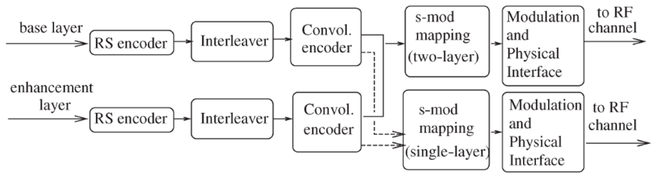
### Overview:

Reusing the current mainstream modulation schemes with software-based bit remapping

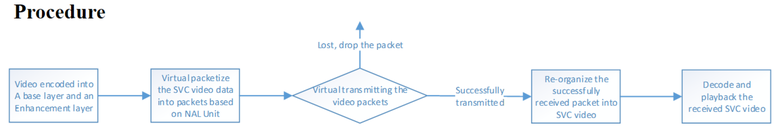
Transmitting different layers of video encoded with Scalable Video Coding (SVC) with different layer

- Base layer transmitted by layer 1, enhancement layer transmitted by layer 2

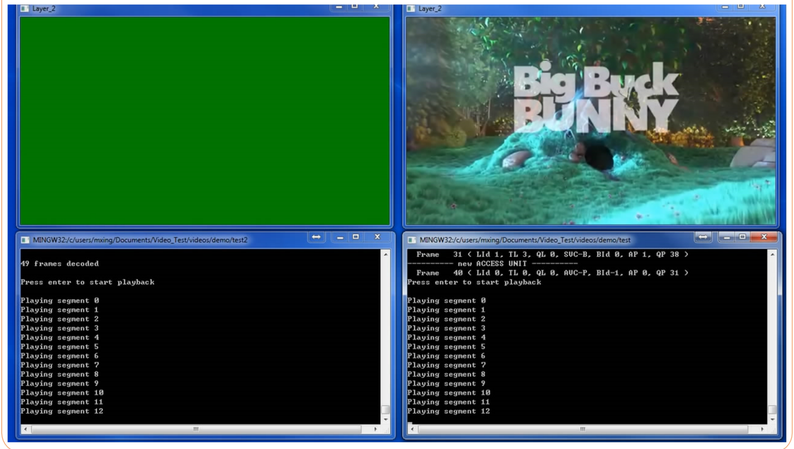



### Procedure




### Experiment screen shot

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[2] Min Xing, Jianping He and Lin Cai, "Maximum-Utility Scheduling for Multimedia Transmission in Drive-Thru Internet," submitted to IEEE Trans. on Veh. Tech.

[3] Lin Cai, Siyuan Xiang, Yuanqian Luo and Jianping Pan, "Scalable modulation for video transmission in wireless networks," IEEE Trans. on Veh. Tech., Vol. 60, Issue 9, pp. 4314--23, Nov. 2011.

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