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Joint Scheduling and Stochastic Streaming for Device-to-Device Video Delivery

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Introduction

- **Device-to-Device (D2D)**
  → Actively discussing in next-generation cellular standards (3GPP)
  → **FlashLinQ** (Allerton 2010), one of several proposals for LTE-Direct

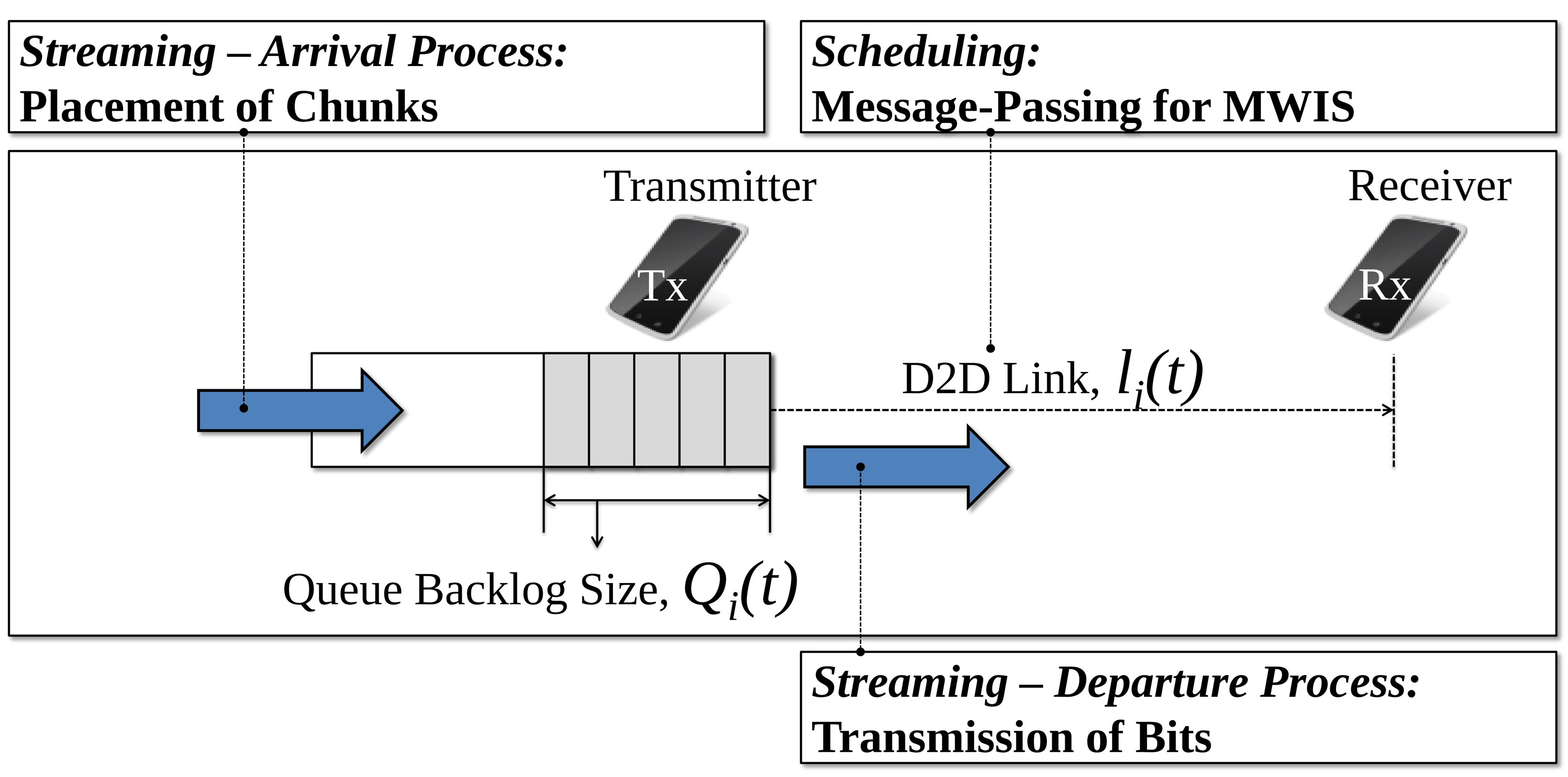
- **FlashLinQ**
  → The most well-known scheduling algorithm in D2D systems
  → However,
  (1) It does not contain video-aware operation,
  (2) It does not consider queue dynamics in D2D transmitters.

Joint Scheduling and Streaming

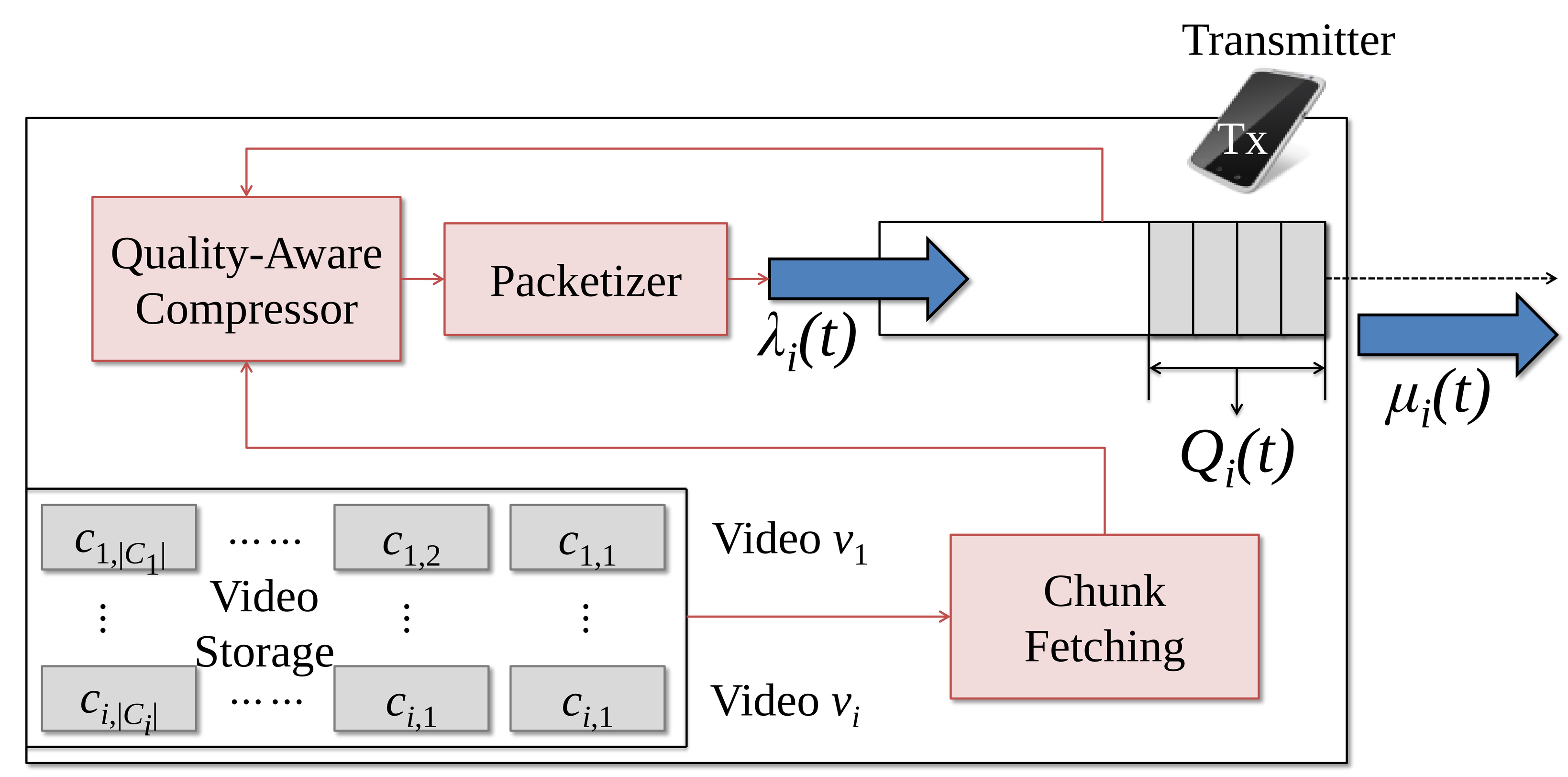
- **Scheduling** with **Max-Weight Independent Set (MWIS) Formulation**
- **Streaming** with **Quality-Awareness** subject to **Queue Rate Stability**

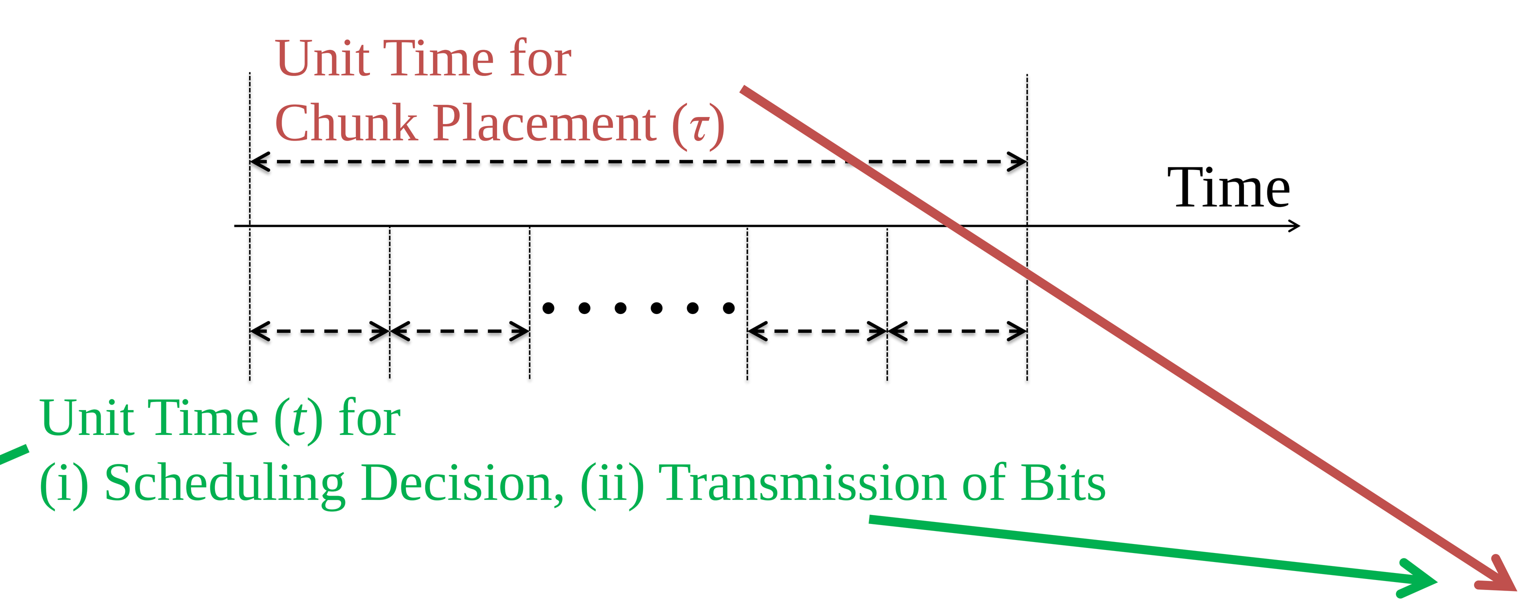
Joint Scheduling and Streaming for Device-to-Device Video Delivery

A Link Model



A Device Model





Scheduling with *MWIS Formulation*

MWIS-Based Scheduling Formulation

$$\max: \quad \mathcal{F}(\mathcal{L},\mathcal{E}) \triangleq \sum\nolimits_{\forall l_i \in \mathcal{L}} w_i \mathcal{I}_i,$$
$$\text{s.t.} \quad \mathcal{I}_j + \mathcal{I}_k \leq 1, \ \text{if } \mathcal{E}_{(j,k)} = 1, \forall l_j \in \mathcal{L}, \forall l_k \in \mathcal{L},$$

where $\mathcal{I}_i$ is a boolean index of $l_i, \forall l_i \in \mathcal{L}$ that is defined as

$$\mathcal{I}_i = \begin{cases} 1, & \text{if } l_i \text{ is scheduled where } l_i \in \mathcal{L}, \\ 0, & \text{otherwise} \end{cases}$$

and $w_i, \forall i \in \{1, \cdots, |\mathcal{L}|\}$ is formulated as follows for *max-weight scheduling*:

$$w_i \triangleq r_i(t) \cdot Q_i(t)$$

Computing the Solutions of MWIS-Based Scheduling via Message-Passing

- Input
  - w_i in (7) where $\forall l_i \in \mathcal{L}$
  - $\mathcal{E}_{(j,k)}$ in (1) where $\forall l_j \in \mathcal{L}, \forall l_k \in \mathcal{L}$
- Output
  - $\mathcal{F}(\mathcal{L},\mathcal{E})$
  - $\mathcal{L}^*$ // set of scheduled D2D links

Update Phase;
$n = 1$;
while $n \leq K$ **do**
  // K: the number of message-passing iteration;
  $m^n_{i\to j} = \max\left[0, w_i - \sum_{k\in\{N(i)-j\}} m^{n-1}_{k\to i}\right], \forall j \in \mathcal{N}(i)$;
  i **sends** $m^n_{i\to j}$ **to all** $j \in \mathcal{N}(i)$;
  $n{+}{+}$;
end
Estimation Phase;

$$\mathcal{I}_i = \begin{cases} 1 & \textbf{if } \sum_{k\in\mathcal{N}(i)} m^K_{k\to i} < w_i \\ 0 & \textbf{otherwise} \end{cases};$$

If $\mathcal{I}_i = 1$ **then** $l_i \in \mathcal{L}^*$;
MWIS Computation Phase;
$\mathcal{F}(\mathcal{L},\mathcal{E}) = \sum_{\forall l_i \in \mathcal{L}} w_i \mathcal{I}_i$;

Sanghavi and Shah NIPS'07

Streaming with *Stochastic Network Optimization*

Streaming (Arrival Process: Placement of Chunks)

Objective Function:
maximization of the total quality over all links subject to the rate stability of all scheduled transmitter queues

$$\max \quad \lim_{t\to\infty} \frac{1}{t} \sum_{t^*=0}^{t-1} \mathbb{E}\left[\mathbb{P}(t^*)\right]$$
$$\text{subject to} \quad \lim_{t\to\infty} \frac{1}{t} \sum_{t^*=0}^{t-1} \mathbb{E}\left[Q_i(t^*)\right] < \infty, \forall l_i \in \mathcal{L}^*$$

Stochastic Optimization

Each Chunk Unit Time, choose *q*,

$$\arg \max_{q_i(t)\in M} \left[\mathbb{P}_{f_i}\left(q_i(t),t\right) - \alpha\left\{k\mathbb{B}_{f_i}\left(q_i(t),t\right)\right\} Q_i(t)\right]$$

where $M = \{q_1, \cdots, q_M\}$

PSNR of Current Chunk with $q_i(t)$

$$\mathbb{P}_{f_i}\left(q_i(t),t\right) = \begin{cases} \mathbb{P}_{f_i}\left(q_i(t),t\right), & \tau \bmod t = 0, \\ 0, & \tau \bmod t \neq 0; \end{cases}$$

Bitrates of Current Chunk with $q_i(t)$

$$\lambda_i(t) = \begin{cases} k\mathbb{B}_{f_i}\left(q_i(t),t\right), & \tau \bmod t = 0, \\ 0, & \tau \bmod t \neq 0, \end{cases}$$

Streaming (Departure Process: TX of Bits)

$$\mu_i(t) = \mathcal{B} \cdot \log_2\left[1 + \frac{\mathcal{P}_{s_i\to r_i}(t)\left\|h_{i\to i}\right\|^2}{\sigma^2 + \sum_{j\neq i}\mathcal{P}_{s_j\to r_j}(t)\left\|h_{j\to i}\right\|^2}\right]$$

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