Packet Video Workshop 2013

Device-to-Device Assisted Video Transmission

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The Motivation

- Mobile video traffic is becoming the main driver of cellular wireless data traffic

- Issues?
  - Increase the data traffic pressures on the cellular network
  - Hard to achieve high quality video transmission

Solution: D2D

- D2D - Device-to-Device communication system
- When two mobile devices are close to each other, transmit video stream directly between two devices
- D2D will help offload the traffic from cellular network

D2D vs. Cellular

- Previously, D2D transmission and cellular transmission are mutually exclusive. Cellular link will be dropped when switching to D2D link.

- We proposed a D2D assisted mode, which keeps both D2D link and cellular link.

D2D Assisted Model

- Conventional link
  - User A transmit to BS through cellular uplink
  - BS forwards packets to user B through cellular downlink

  The data rate is the minimum of the data rate in the uplink and the downlink

- D2D link
  - User A transmit directly to user B without going through BS

  Maximize the D2D link data rate under the power control mechanism

D2D Assisted Model

- User A and user B are D2D pair
- C1, C2, C3 are cellular users
- User A transmits video both on cellular link through BS and on D2D link which share frequency with C2

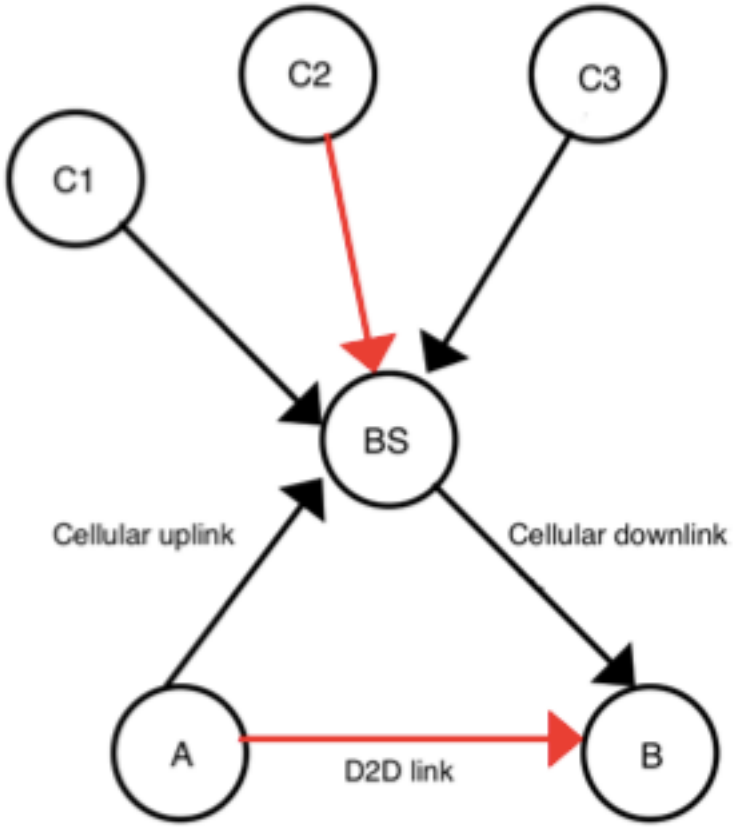


Fig. 1: D2D assisted model

D2D Assisted Model

Enable D2D link scenario

- In the cellular network, one base station (BS) serves N cellular users
- Orthogonal uplink and downlink frequencies are assigned to each user by BS
- User A will transmit video stream to user B
- User A and user B are geographically close to each other
- BS enable D2D link and assign an uplink frequency to share
- User A transmit the video on two links simultaneously

D2D Assisted Model

Disable D2D link scenario

- D2D channel condition goes bad
- A drop in the quality of D2D link is significant
- Disable the transmission on D2D link
- Video is only transmitted through the conventional link
- The reused uplink frequency is released

D2D Mode Selection

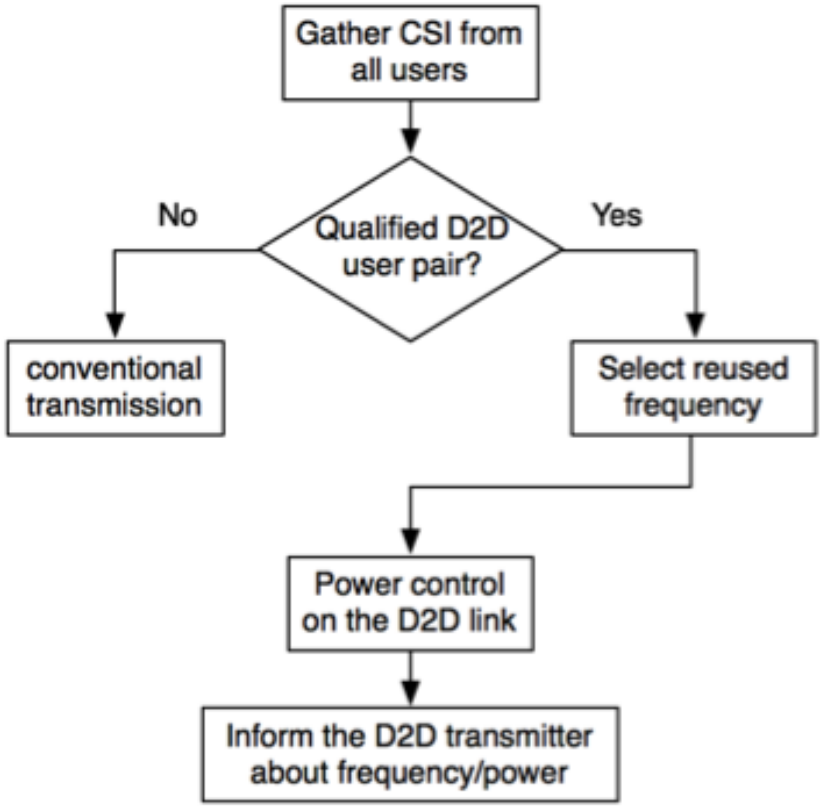
Select enable or disable D2D assisted mode in every GOP set

GOP set: contains a sufficient large number of GOPs, so that the computation overhead is negligible

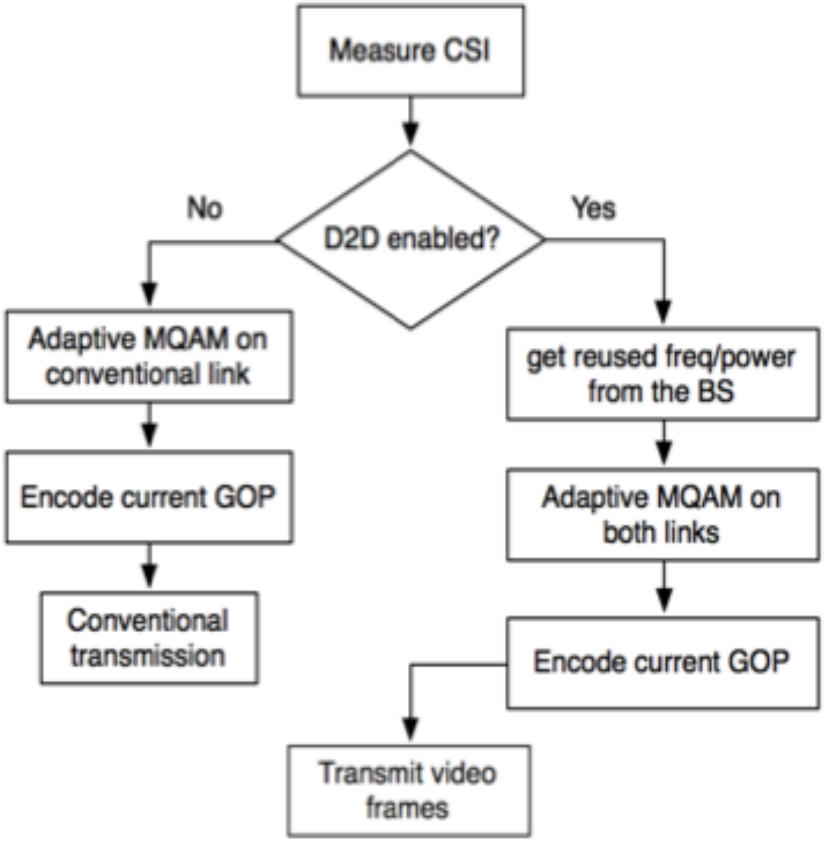
- Algorithm at BS: select the reused frequency and notify the D2D transmitter of the power limit

- Algorithm at D2D transmitter: select the constellation size of each link by adaptive MQAM

D2D Mode Selection



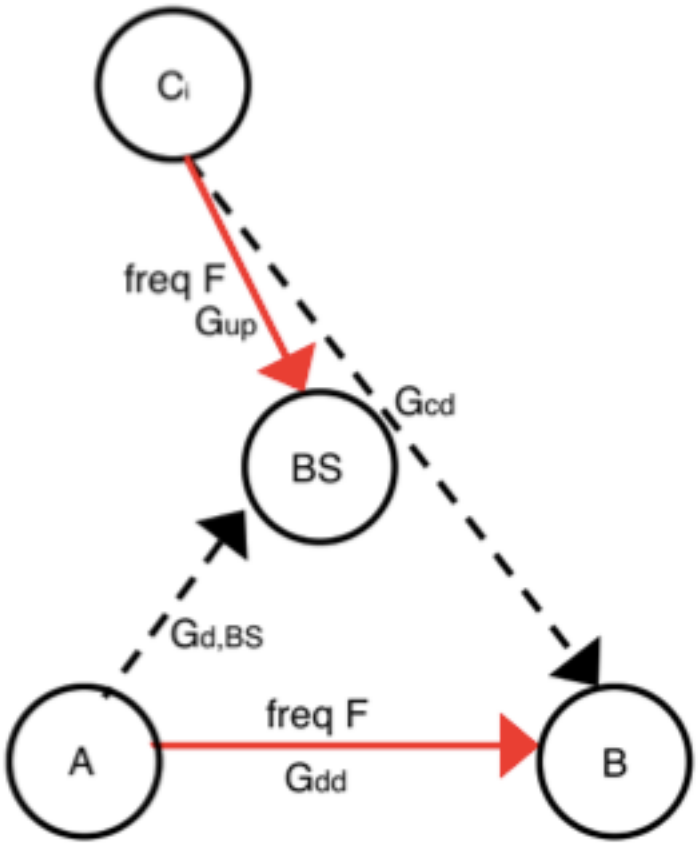
(a) Algorithm at the BS



(b) Algorithm at the D2D transmitter

Power control

- Reuse the uplink cellular frequency will cause interference both on BS and D2D receiver (User B)
- D2D transmitter (User A) will interference the BS
- Cellular user which shares the uplink frequency (C_i) with will cause interference at the D2D receiver



Power control

- Constraint the power of D2D transmitter so that the cellular user who shares the link will not experience severe hurt
  - Measure the $SINR_{BS}$ at the cellular user receiver
  - Limit the downgrade of the $SINR_{BS}$ by threshold η

$$SINR_{BS}'(dB) \geq \eta \, SINR_{BS}(dB)$$

$SINR_{BS}$ ' (dB): with the interference from D2D transmitter

$SINR_{BS}$ (dB) : without the interference

- Determine the maximum transmit power on D2D link: P_{dd}

$$P_{dd} \leq \frac{(P_{up}G_{up})^{1-\eta}(NW)^{\eta} - NW}{G_{d,BS}}$$

Frequency selection

- Choose a cellular user to reuse its frequency that maximizes the SINR at the D2D receiver: $SINR_{dd}$

$$SINR_{dd} = \frac{((P_{up}G_{up})^{1-\eta}(NW)^{\eta} - NW)\frac{G_{dd}}{G_{d,BS}}}{NW + P_{up}G_{cd}}$$

- Then reuse the uplink frequency of this user

  (Since downlink is always heavily used, so we share uplink)

Channel Model

A comprehensive channel model is considered

- Path loss

  Receive power P_r is inversely proportional to the power of transmission distance

- Shadow fading

  log-normal distribution

- Multi-path fading

  Slow Rayleigh fading

Adaptive MQAM

- All users are supposed to employ an adaptive MQAM format.
  - D2D transmitter is QAM modulated by size M_1
  - Cellular user who shares frequency is modulated by size M_2
- We use the worst-case symbol error rate (SER) to analyze
  - Signal symbol use the lowest amplitude
  - Interference symbol uses the highest amplitude
- D2D transmitter will choose the largest possible QAM size so that the SER will be less than a preset threshold

Video Model

Encoder

- Raw YUV video sequence is compressed by H.264
- Inter-coded as I B B P
- One GOP is one second with 30 frames
- Fixed one slice with 128 bytes
- Rate control: use transmission rate determined in physical layer to control the encoding rate for each GOP

Decoder

- Slice copying is used for error concealment

Evaluation Metrics

Compare the D2D assisted mode with the conventional mode from two aspects:

- The sum throughput of all users

  Sum of expected number of correct bit of all the uplinks and D2D link, and compare with the sum in conventional mode

- Video quality

  At the receiver side, measure the PSNR when D2D assisted mode is enabled, and compare that with the scenario where only has conventional mode

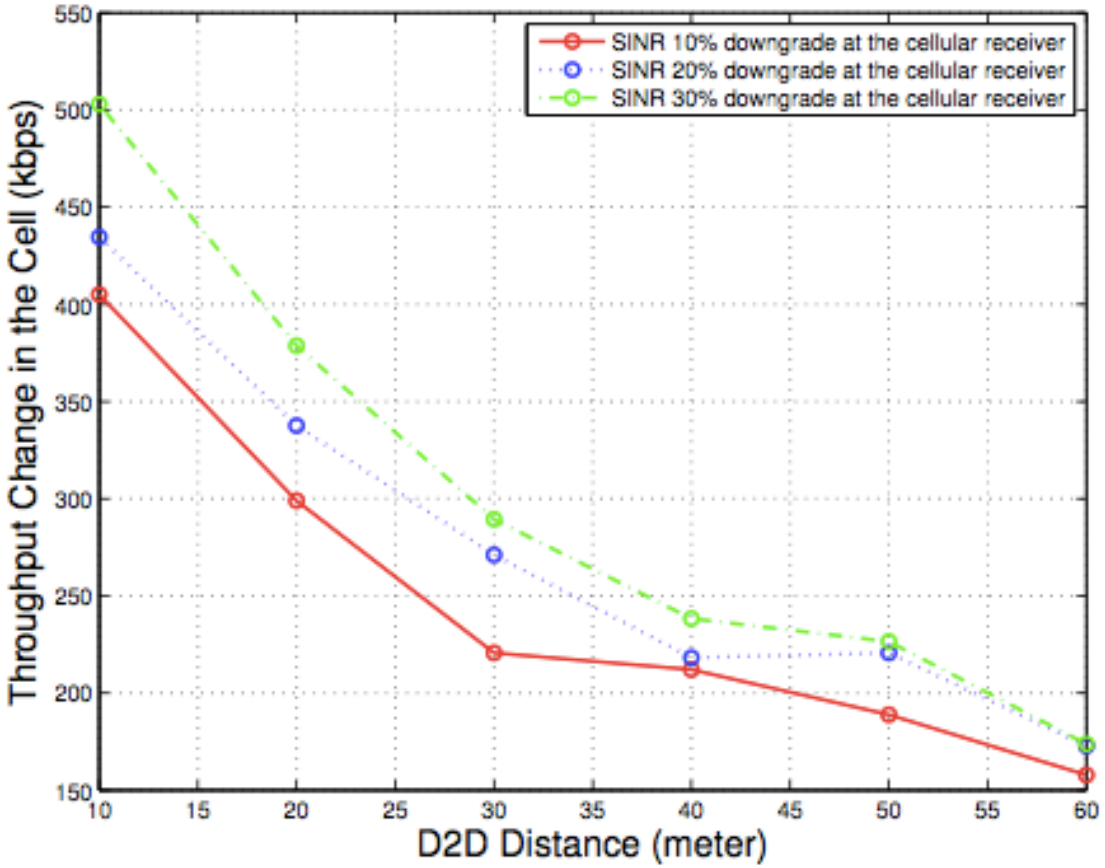
Simulation Parameters

- Cell size: 100-by-100 meters
- Orthogonal frequency slot bandwidth: 100kHz
- Maximum transmission power of cellular user: 100mW
- BS serves 10 cellular users and 1 D2D pair
- 10 GOPs in one GOP set
- MQAM SER threshold: 0.2

Simulation Parameters

Interference threshold at the cellular receiver: 20% SINR downgrade

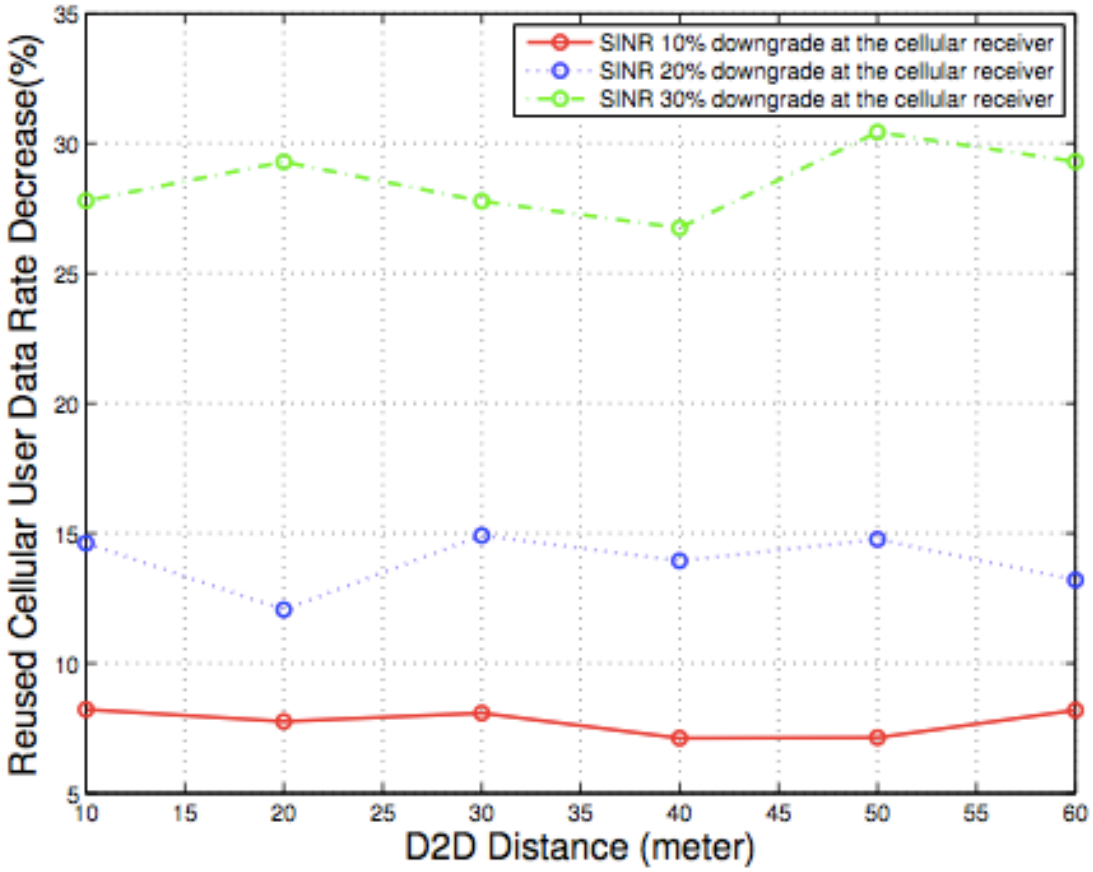
- Throughput change in a cell when D2D link is enabled



Simulation Parameters

Interference threshold at the cellular receiver: 20% SINR downgrade

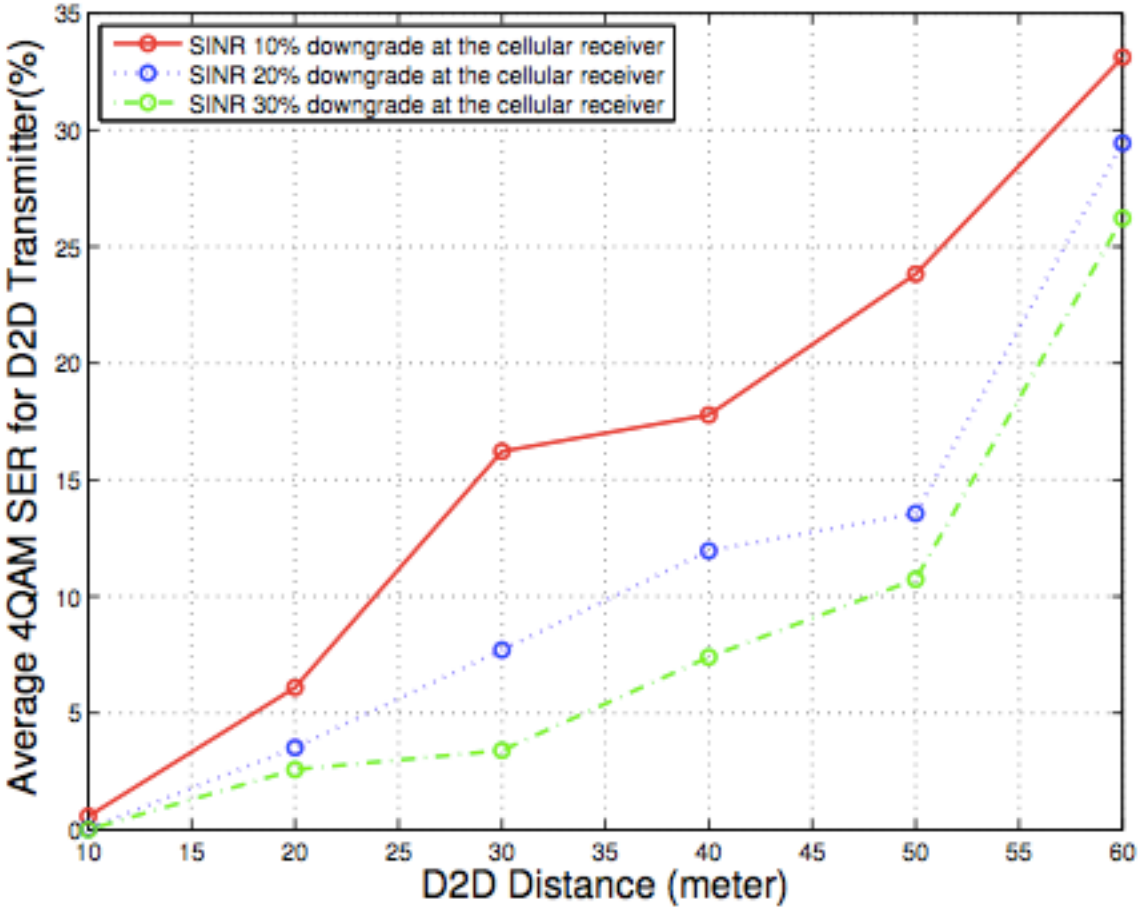
- Cellular data rate downgrade due to the D2D link interference



Simulation Parameters

Interference threshold at the cellular receiver: 20% SINR downgrade

- 4QAM SER for the D2D link



Simulation

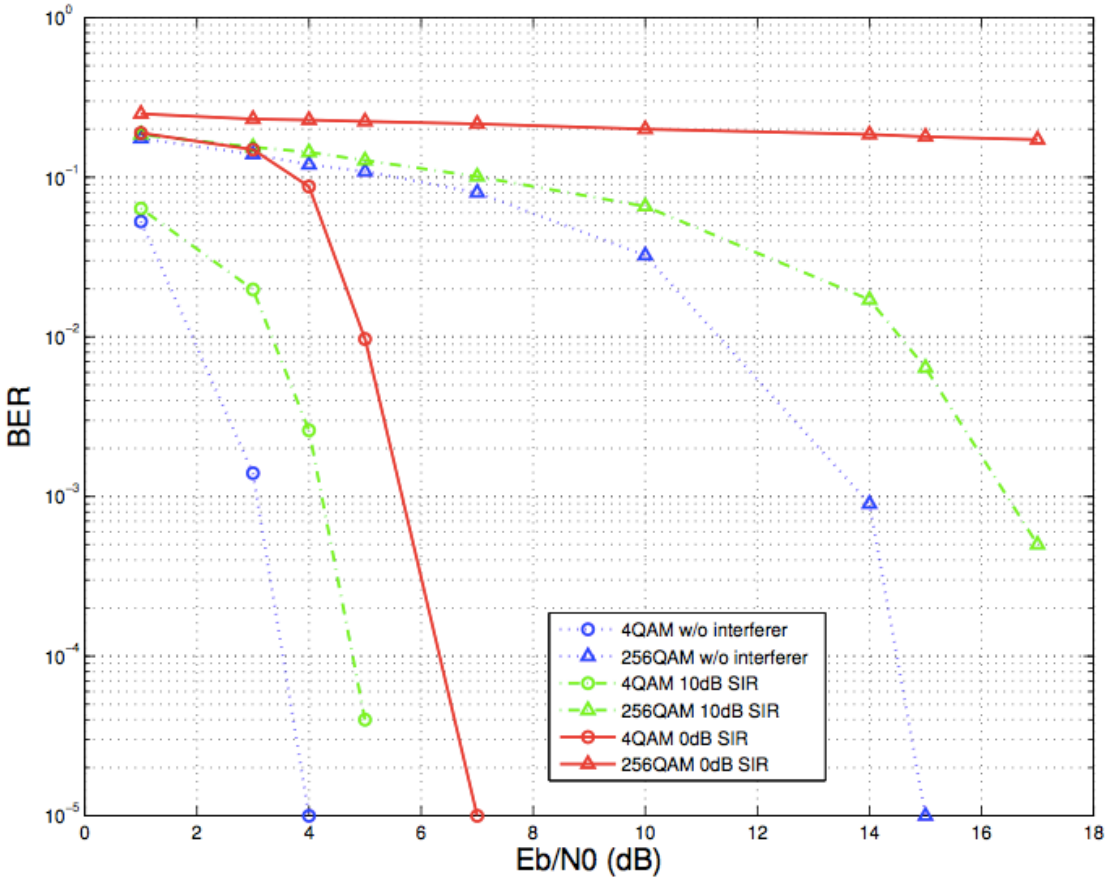
D2D Assisted Model Feasibility

- BER of D2D link under three levels of interference

No interference

Moderate (SIR=10dB)

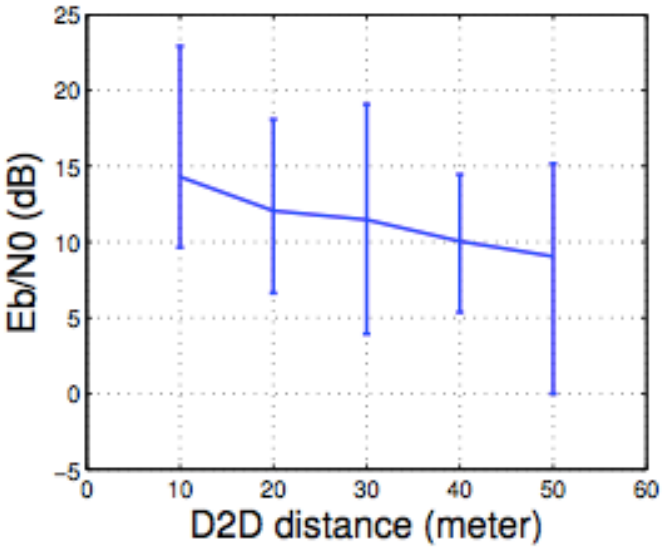
Severe (SIR=0dB)

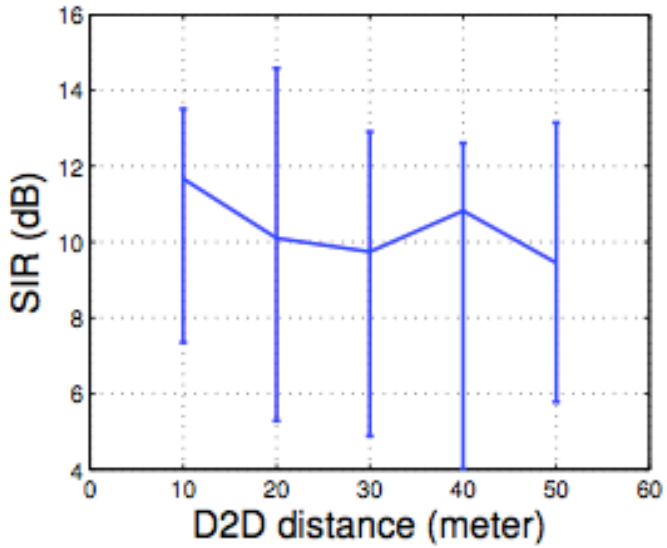


Simulation

D2D Assisted Model Feasibility

- Average channel gain of D2D link





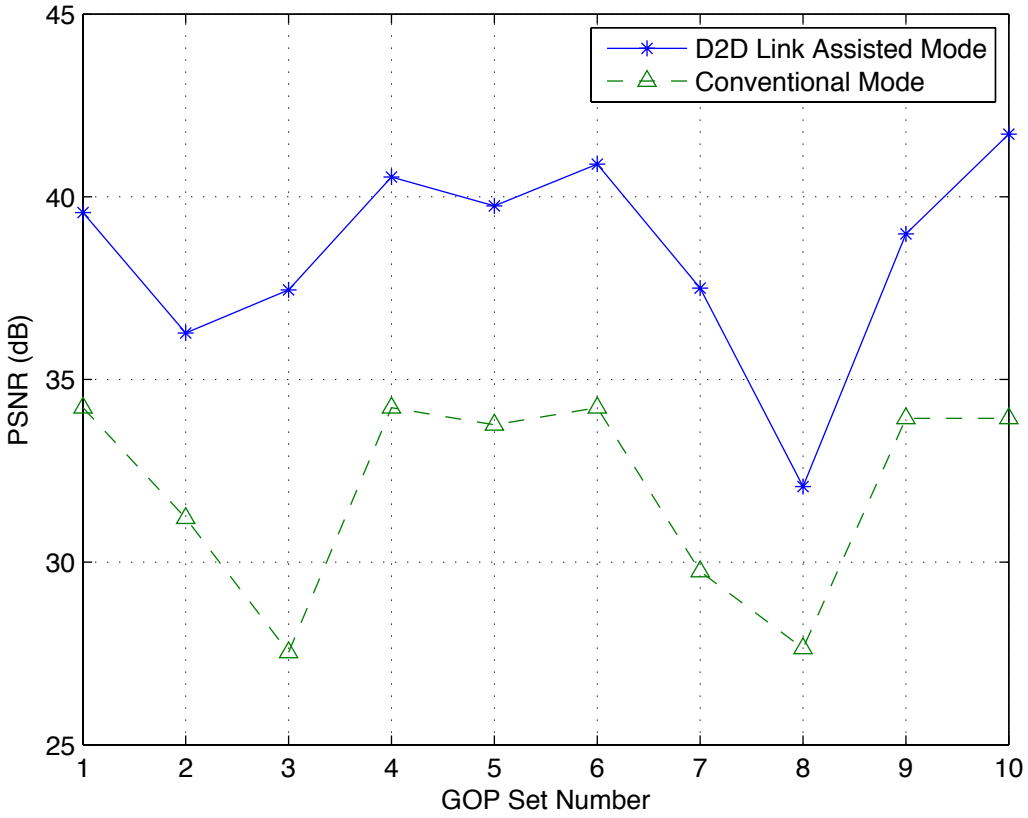
It proves that an appropriate modulation scheme to transmit video with a BER of 10^{-5} could be found

Simulation

Video reception quality

Transmit a 640×480 SDTV video, with 4:2:0 sampling format

PSNR in D2D assisted mode has a improvement of 8dB to 10dB compared to the conventional mode



Conclusion

With the assistance of D2D link when transmitting video in cellular network, we can

- Increase the sum throughput in a cell
- Improve the video reception quality for the D2D enabled receiver

Thank you.