NCTU

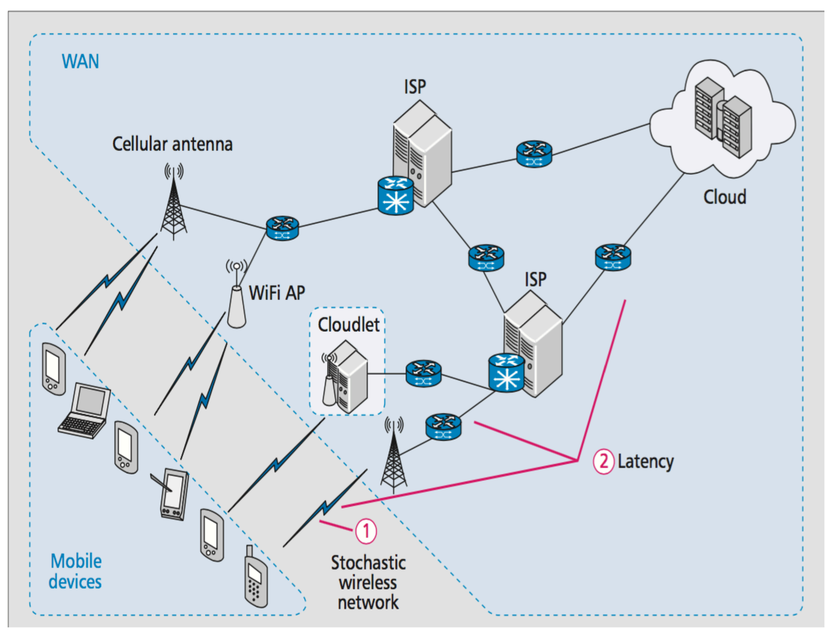
國立交通大學 電機工程學系
Department of Electrical and Computer Engineering

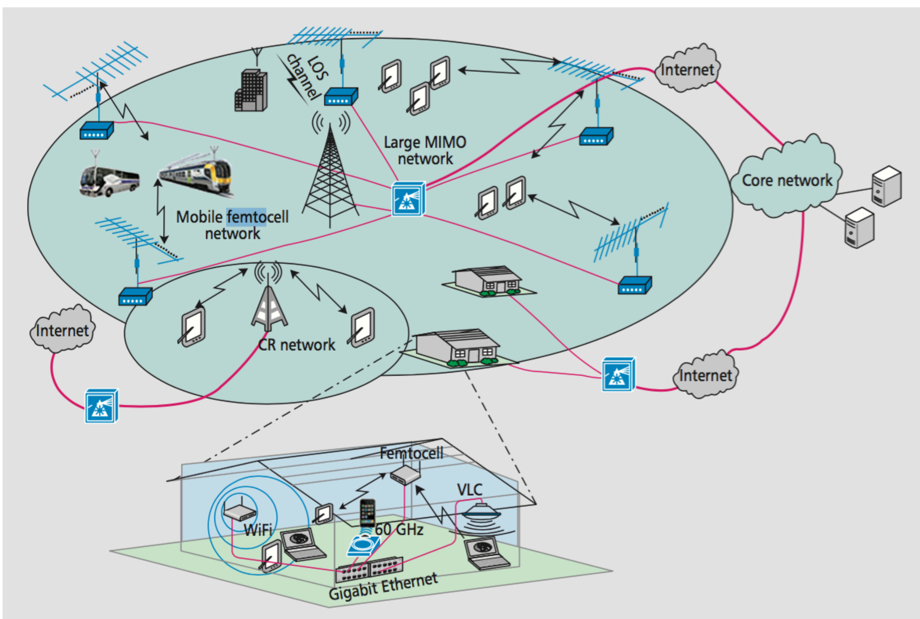
5G Millimeter Wave Radio Resource Management

指導老師：方凱田教授　　　專題生：鍾兆翔、楊騰

Ⅰ、Introduction

- The increased rate demand in the upcoming 5G wireless systems and the fact that the spectral efficiency of microwave links is approaching its fundamental limits have motivated consideration of higher frequency bands that offer abundance of communication bandwidth.
- Different solutions. Cloud computing, Femtocell, Millimeter wave, etc.
- There is a growing consensus in both industry and academia that millimeter wave (mmWave) will play an important role in 5G wireless systems in providing very high data rates.

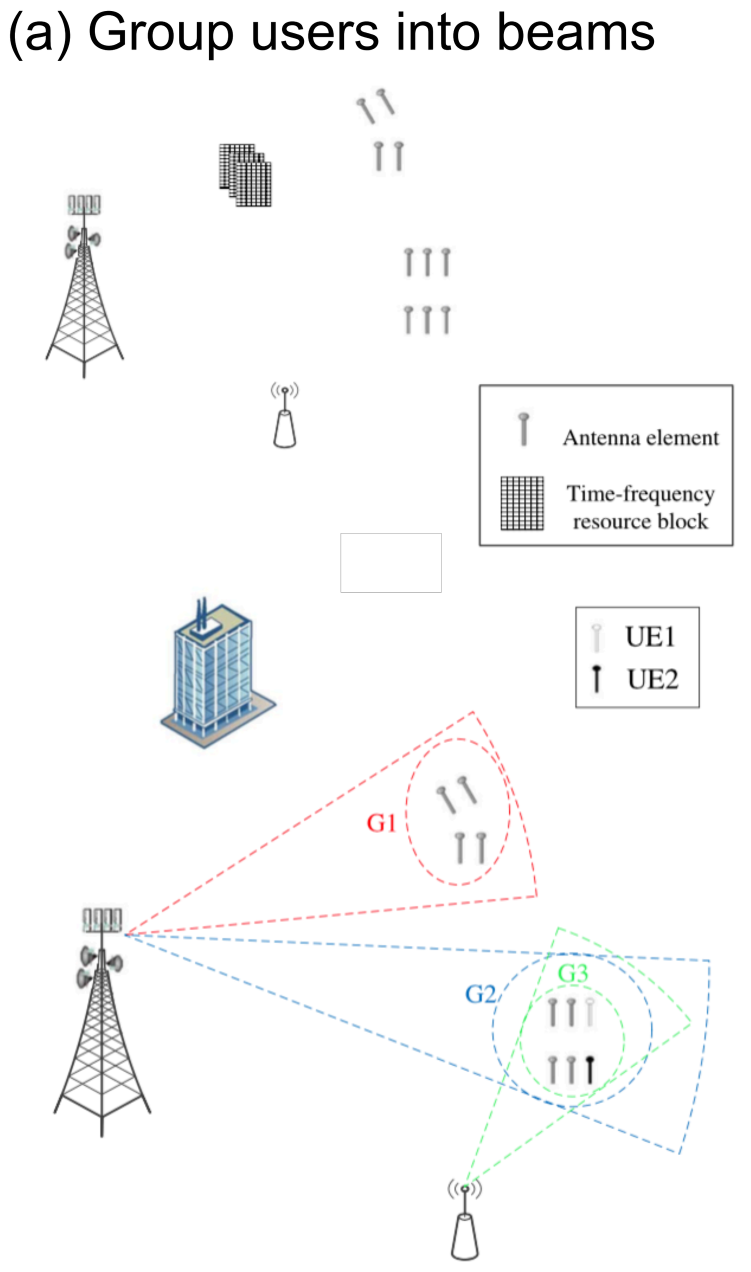

(a) Cloud Computing


(b) Femtocell

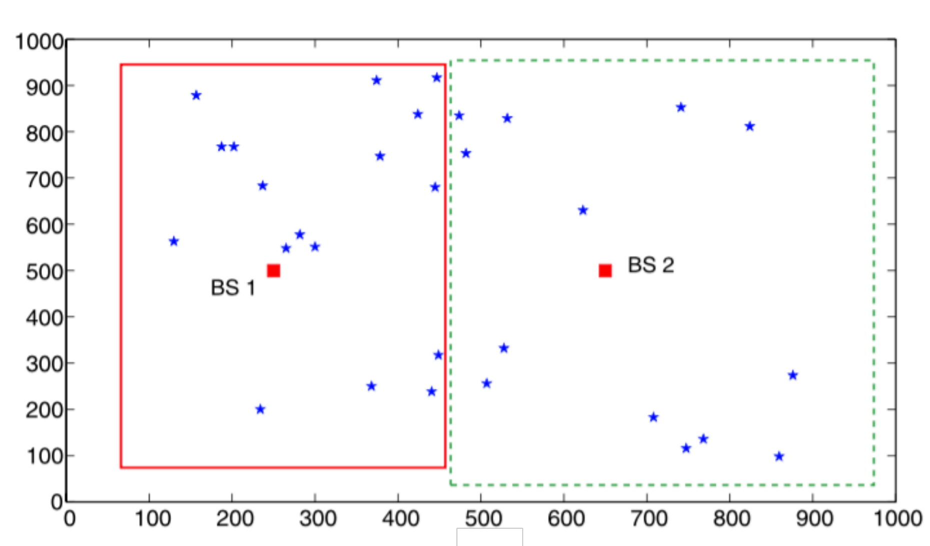
Ⅱ、Millimeter wave

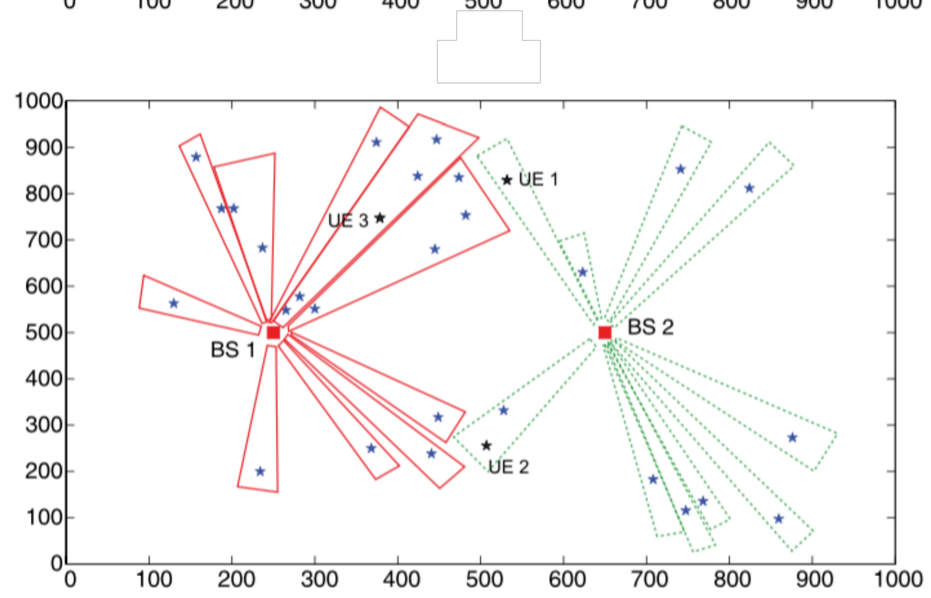
- The spectral efficiency of microwave links is approaching its fundamental limits. That's why we need an alternative.
- Millimeter wave (mmWave) will play an important role in 5G wireless systems in providing very high data rates, larger bandwidth, and directional beams.
- Resource Allocation and Interference Management: The directional pencil-beam operation provides many options to form different cells and allocate resources, while significantly simplifying interference management. We identify new trade-offs among throughput enhancement, fair scheduling, and formulate a suitable optimization problem based on long-term resource allocation. Finally, we use directional beams at the BSs and/or the UEs.

(a) Group users into beams



(b) Omnidirectional beams





(c) Unidirectional beams

Ⅲ、Performance Evaluation

- Consider one millimeter wave (mmWave) base station (BS). We have K users served by M beam, where K>M. We need to group users based on feedback channel loss information. For each beam, we have different transmit power $P_{k,m}$ and beamwidth $\theta_{k,m}$ which uses same frequency.

- For each user, we have different channel conditions given by

$$H_{k,m}(d_k) = h_{k,m} {d_k}^{-\alpha}$$

- $H_{k,m}$ is channel loss In m-th beam in k-th user
- d_k is distance from k-th user to BS
- α is fading exponent
- $h_{k,m}$ is channel fading effected by environment

- Beam gain is expressed as

$$g(\theta) = \begin{cases} \frac{c}{\theta}, & serving\ signal\ mainlobe\ gain \\ \varepsilon, & interference\ sidelobe\ gain \end{cases}$$

Signal-to-interference-plus-noise ratio (SINR) for k-th user as

$$\gamma_{k,m} = \frac{P_{k,m} g(\theta_{k,m}) h_{k,m}(d_k)\phi_{k,m}}{\sum_{i\neq m}^{M} P_{k,i} g(\theta_{k,i}) h_{k,i}(d_k) + N_o W}$$

$P_{k,m}$ is signal transmit power in m-th beam to k-th user
$P_{k,i}$ is interference transmit power i-th beam to k-th user
$g(\theta_{k,m})$ is signal beam gain and $g(\theta_{k,i})$ is interference beam gain
$h_{k,m}(d_k)$ is signal channel loss for k-th user in m-th beam to BS
$h_{k,i}(d_k)$ is interference channel loss for k-th user in i-th beam to BS
$\phi_{k,m}$ is 0-1 value indicated if k-th user is grouped in m-th beam
N_0 is thermal noise
W is bandwidth

Total system data rate given by Shannon function is

$$R_{tot} = \sum_{k=1}^{K}\sum_{m=1}^{M} \frac{1}{\sum_{i=1}^{K}\phi_{i,m}} W log_2(1+\gamma_{k,m})$$

$\sum_{i=1}^{K}\phi_{i,m}$ is amount of user in m-th beam
$1/\sum_{i=1}^{K}\phi_{i,m}$ is gotten data rate by one user in that beam

We want to maximize system data rate but constrained by

$P_{k,m} \leq P_{max}$

$\sum_{m=1}^{M}\phi_{k,m} = 1$

K > M

- Gradient Descendent Method

$$R(P_{k,m}) = \sum_{k=1}^{K}\sum_{m=1}^{M} \frac{1}{\sum_{i=1}^{K}\phi_{i,m}} W log_2\left(1+\frac{P_{k,m}a_{k,m}}{\sum_{i\neq m}^{M} b_{k,i}+c}\right)$$

$$a_{k,m} \coloneqq g(\theta_{k,m}) h_{k,m}(d_k)\phi_{k,m} \qquad b_{k,m} \coloneqq P_{k,i} g(\theta_{k,i}) h_{k,i}(d_k) \qquad c \coloneqq N_o W$$

$$|\nabla R(P_{k,m})| = \frac{\partial R(P_{k,m})}{\partial P_{k,m}} = \frac{1}{\sum_{i=1}^{k}\phi_{i,m}} \cdot \frac{W}{\log_e 2} \cdot \left\{ \frac{\left(\frac{a_{k,m}}{\sum_{i\neq m}^{M} b_{k,i}+c}\right)}{1+\frac{P_{k,m} g(\theta_{k,m}) h_{k,m}(d_k)\phi_{k,m}}{\sum_{i\neq m}^{M} b_{k,i}+c}} - \sum_{w\neq m}\left(\frac{1}{\sum_{j\neq w} P_{k,j}b_{k,j} + P_{k,w}a_{k,w} + c} \cdot \frac{P_{k,w}a_{k,w}b_{k,m}}{\sum_{j\neq w} P_{k,j}b_{k,j}+c}\right) \right\}$$

Given a starting point P

Repeat

1. $\Delta P = -\nabla R(P)$
2. Backtracking line search:

   Given a descent direction ΔP for R at P

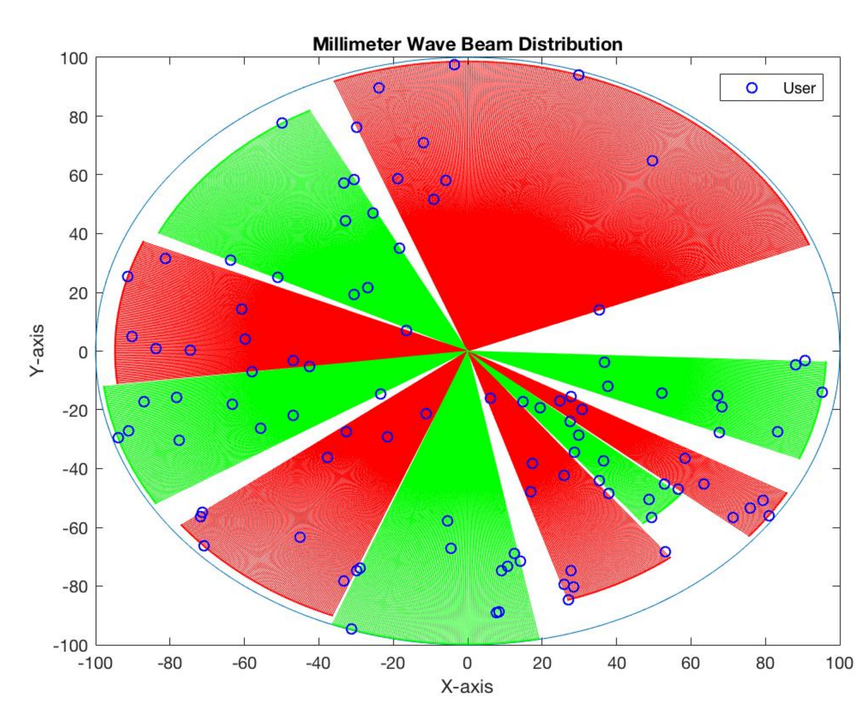
   $\gamma \in (0, 0.5)$, $\beta \in (0, 1)$, $t \coloneqq 1$

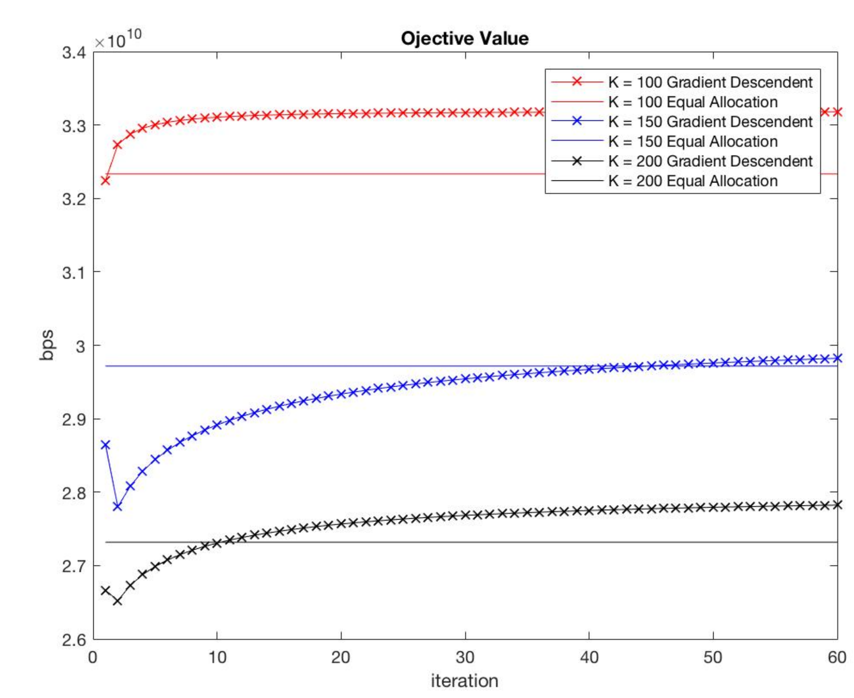
   While $R(P+\Delta P) > R(P) + \gamma t \nabla R(P)^T \Delta P$, $t \coloneqq \beta t$
3. Update: $P \coloneqq P + t\Delta P$

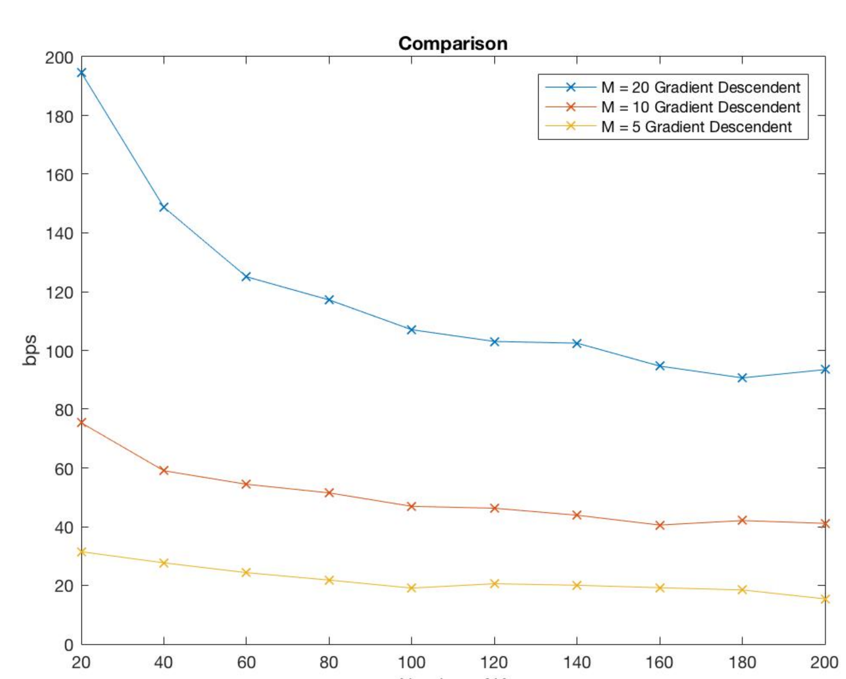
Until stopping criterion is satisfied

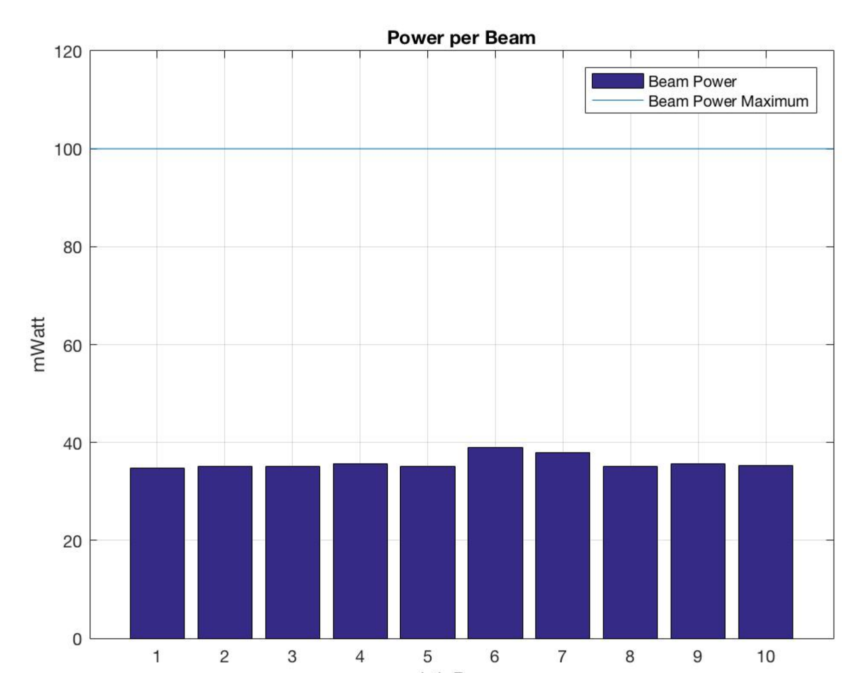
	Spec.	Value
Fading exponent	α	4
Beam gain parameter	c	2π
Interference gain	ε	0.1
Bandwidth	W	200 MHz
Thermal noise	N_0	-174 dBm/Hz
Max transmit power	P_{max}	30 dBm
Radius BS serves	radius	100 m
#of users	K	100
# of beams	M	10

Ⅳ、Simulation Result









Ⅴ、Future Work

- The overlap between beams
  - Users may be in two or more beams
- More method in comparison
  - Brute force
- Different resource allocation
  - Beams may cover different number of users

References

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