Multi-resolution Precoding Codebook for MIMO Downlink Transmission Schemes

Document Number:
IEEE S802.16m-08/333
Date Submitted:
2008-05-12
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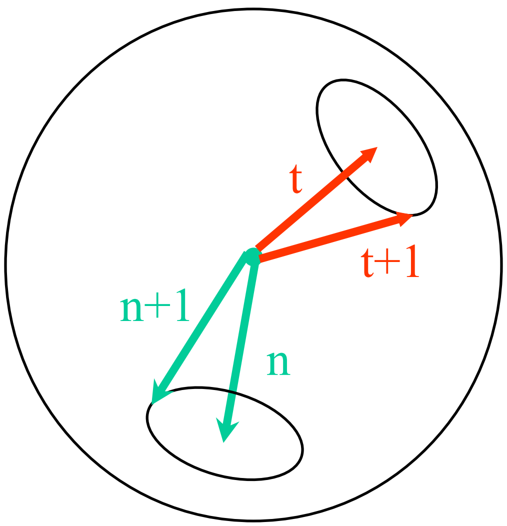
Venue:
IEEE 802.16m-08/016r1, Call for SDD Comments and Contributions (2008-03-20)
Base Contribution:
IEEE 802.16m-08/333
Purpose:
Discussion and Decision
Notice:

Release:

Patent Policy:

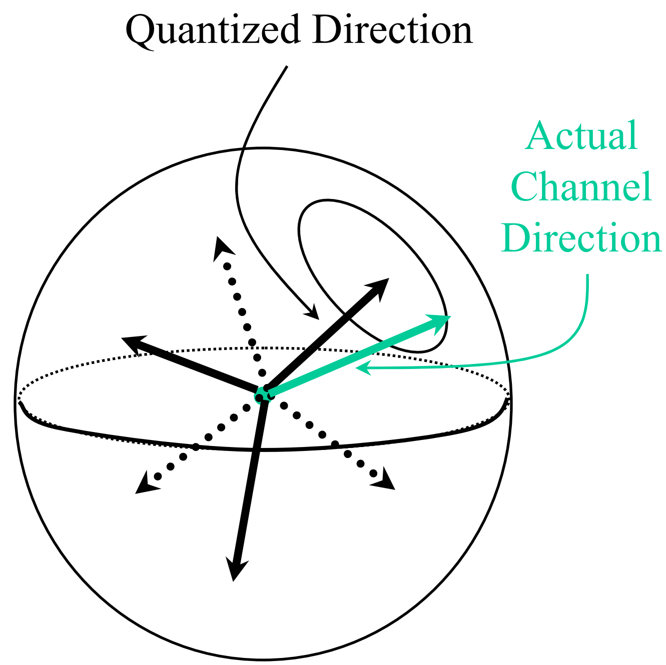
Main Idea

- Consider $N_T \times N_R$ MIMO channel
- Consider the space of all precoders of size $N_T \times K$, $K \leq N_R$ and a proper distance metric on it.
- The optimal precoder for two channel realizations that are very correlated are almost similar or very close (with respect to the distance metric)
- Figure illustrates (just for
  - a precoder as a vector
  - Space of precoders as a sphere
- Time correlation: time t, t+1
- Frequency correlation: resource block n, n+1



Quantized Codebook

- Figure illustrates a set of 6 precoders as the possible quantization codebook
- Solid (dotted) line shows the vector in front (back) of the sphere
- Instead of the actual channel direction, only the index of the closest precoder is fed back



Multi-Resolution Quantization Codebook

- Figure 1 illustrates the first level resolution codebook
- Figure 2 illustrates the second level resolution codebook
  - a set of 6 precoders in vicinity of a given precoder on the sphere
- The second level resolution codebook can be obtained in several ways
  - Individual optimization of the 2^{nd} level codebook entries for each vector in the 1^{st} level codebook
  - Obtaining 2^{nd} level codebooks as a transformation (e.g., unitary rotation) of a single codebook (average performance optimization)

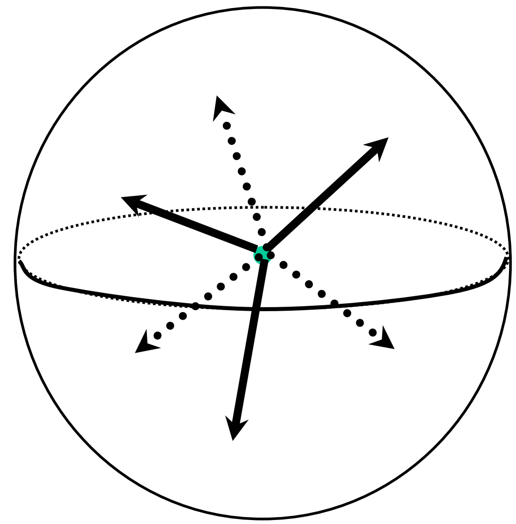


Figure 1

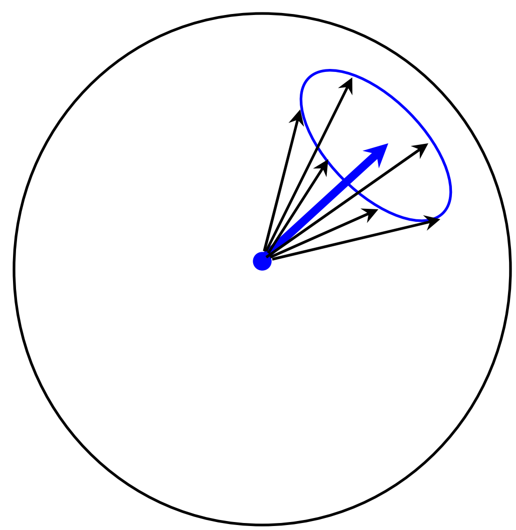


Figure 2

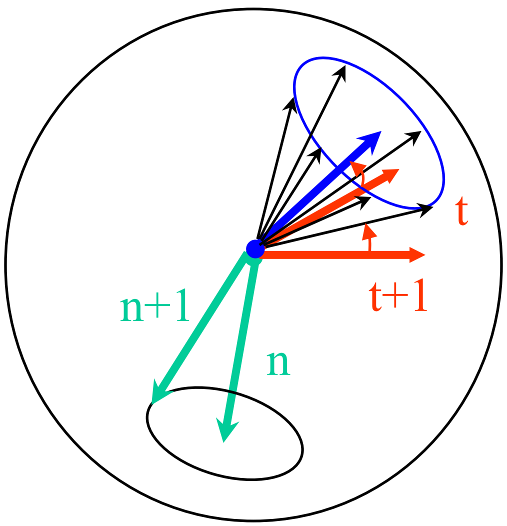
Application of Multi-Resolution Codebook

- Figure illustrates two actual channel directions at time t and t+1

- If the channel directions are close, the channel direction at time t+1 can be quantized by using the second resolution codebook

- The second resolution codebook provides better quantization without increasing the feedback load

- The same concept can be used for the quantization of two adjacent resource block n, n+1

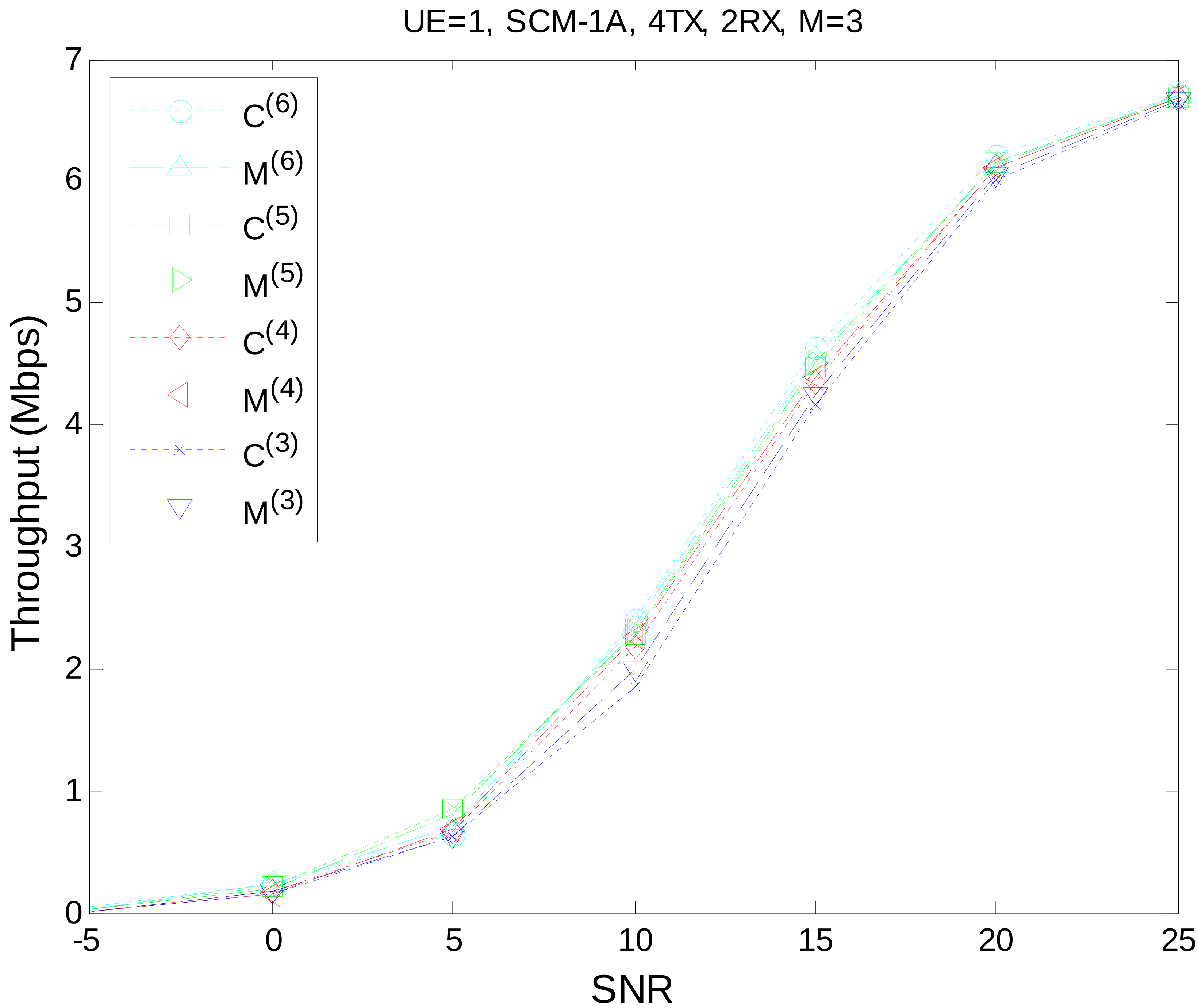


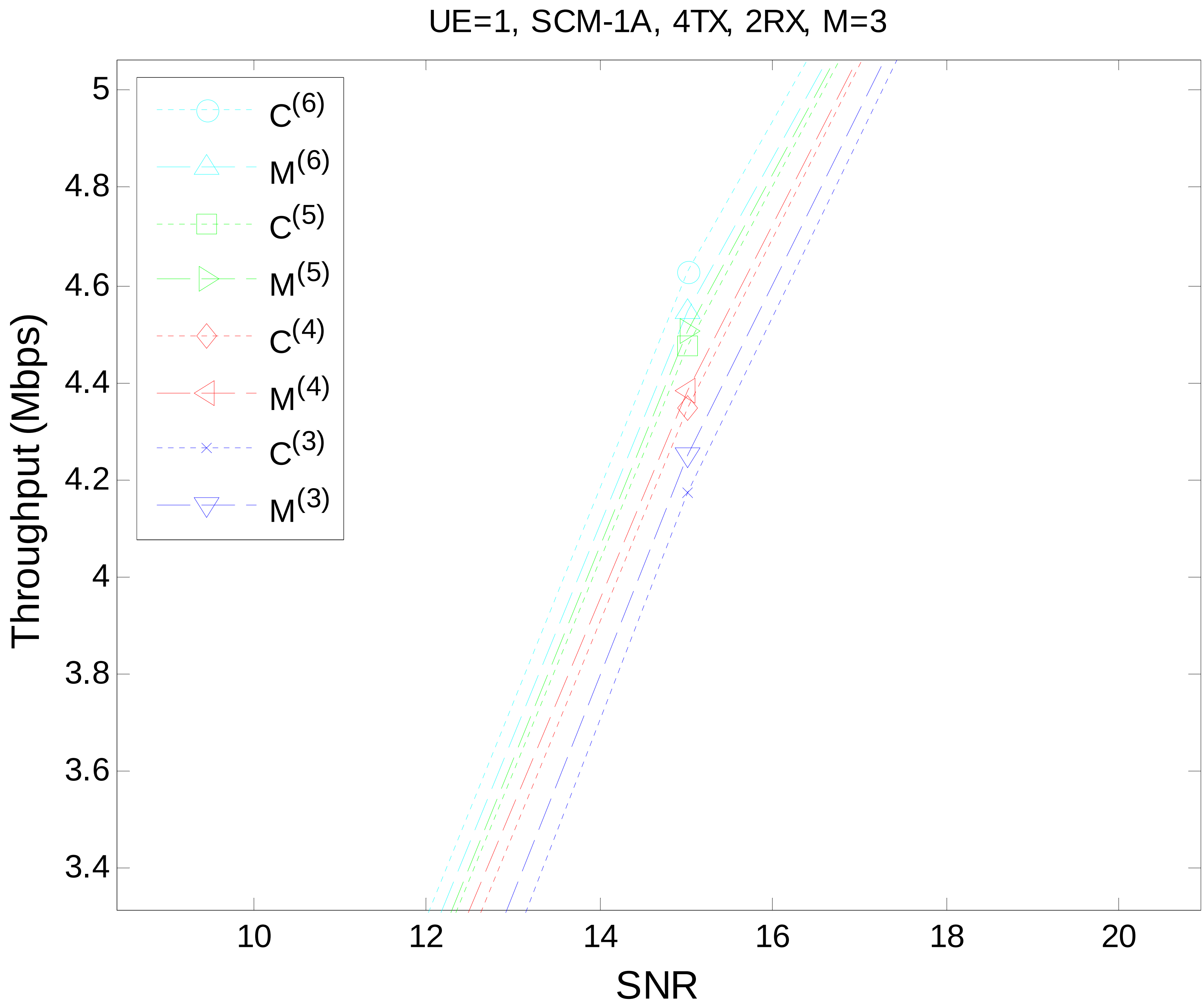
Simulation Setup

Parameter	**Assumption**
Access	OFDM
RF carrier frequency	2.0 GHz
Bandwidth	10.0 MHz
Number of paths (Multi-path model)	6
Sub-carrier spacing	10.9375 kHz
Sampling frequency	11.2 MHz
Number of occupied sub-carriers	720
Number of OFDM symbols / frame	47
Frame duration	5ms
Number of subcarriers per slot (RB)	24 x 2 per 2 OFDM symbols
CP length	(1/8)*102.86 micro second
FFT point	1024
Number of antennas at BS	4
Number of antennas at MS	2
Codebook size (in bits)	3,4,5,6 bits for low- resolution, 3 bits for high-resolution
Number of the resource blocks (M)	3,7,11
Channel models	SCM channel model case 1A: 3kmph, L=6
Channel estimation	Ideal channel estimation
MCS	4, 16 and 64 QAM, code rates 1/2, 2/3, 3/4 and 5/6
Quantization codebook	Single-resolution:IEEE802.16e, Multi-resolution:Design

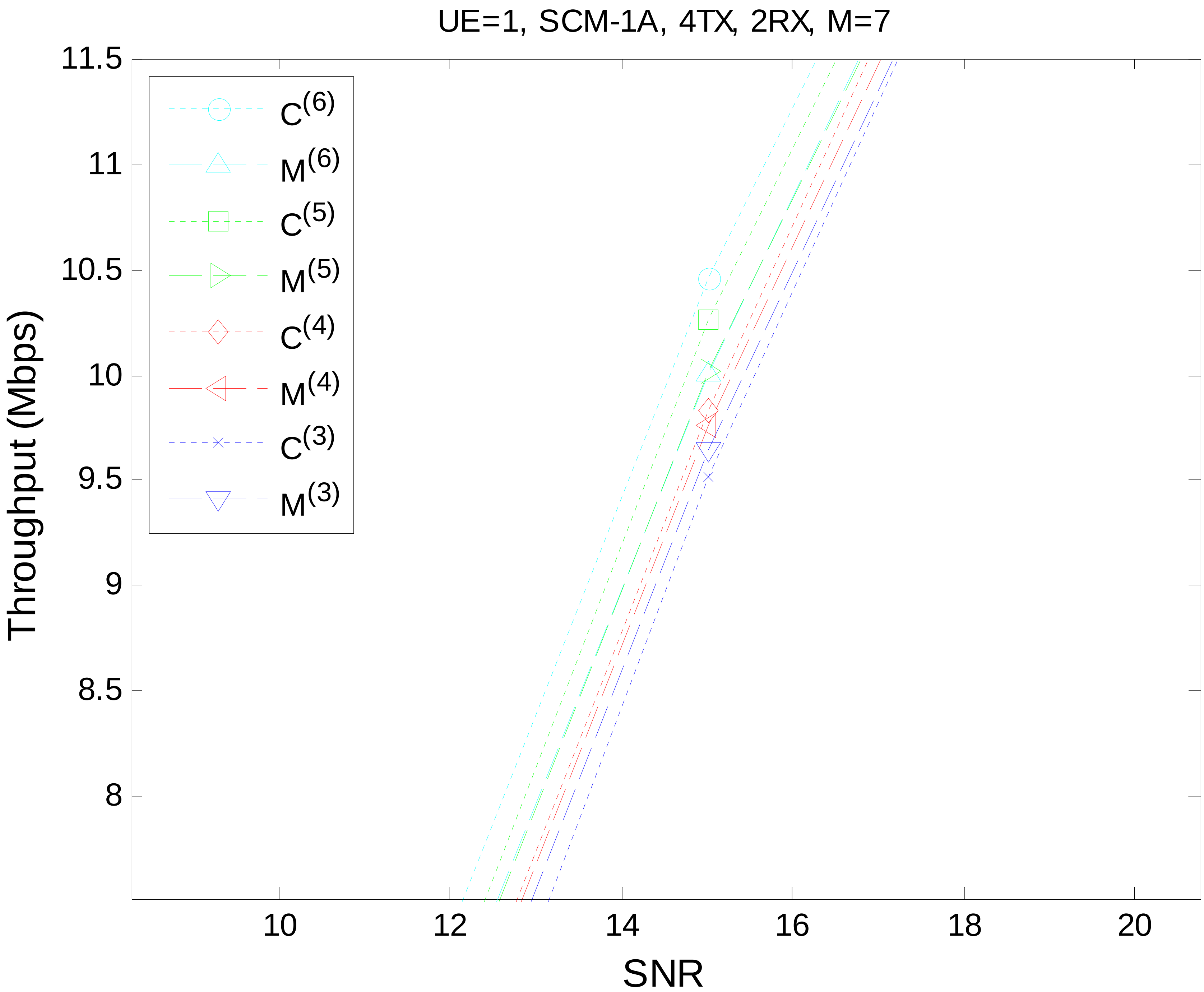
Simulation Results

- 4TX, 2RX
- M= 3, 7, 11 adjacent resource blocks
- Single-resolution codebook with B bits C(B)
- Multi-resolution codebook
  - M(B): 1st level C(B), second level 3 bits: Unitary rotation
  - N(B): 1st level C(B), second level 3 bits: Individual optimization
  - O(B): 1st level C(B), second level 3 bits: Individual optimization, nested structure

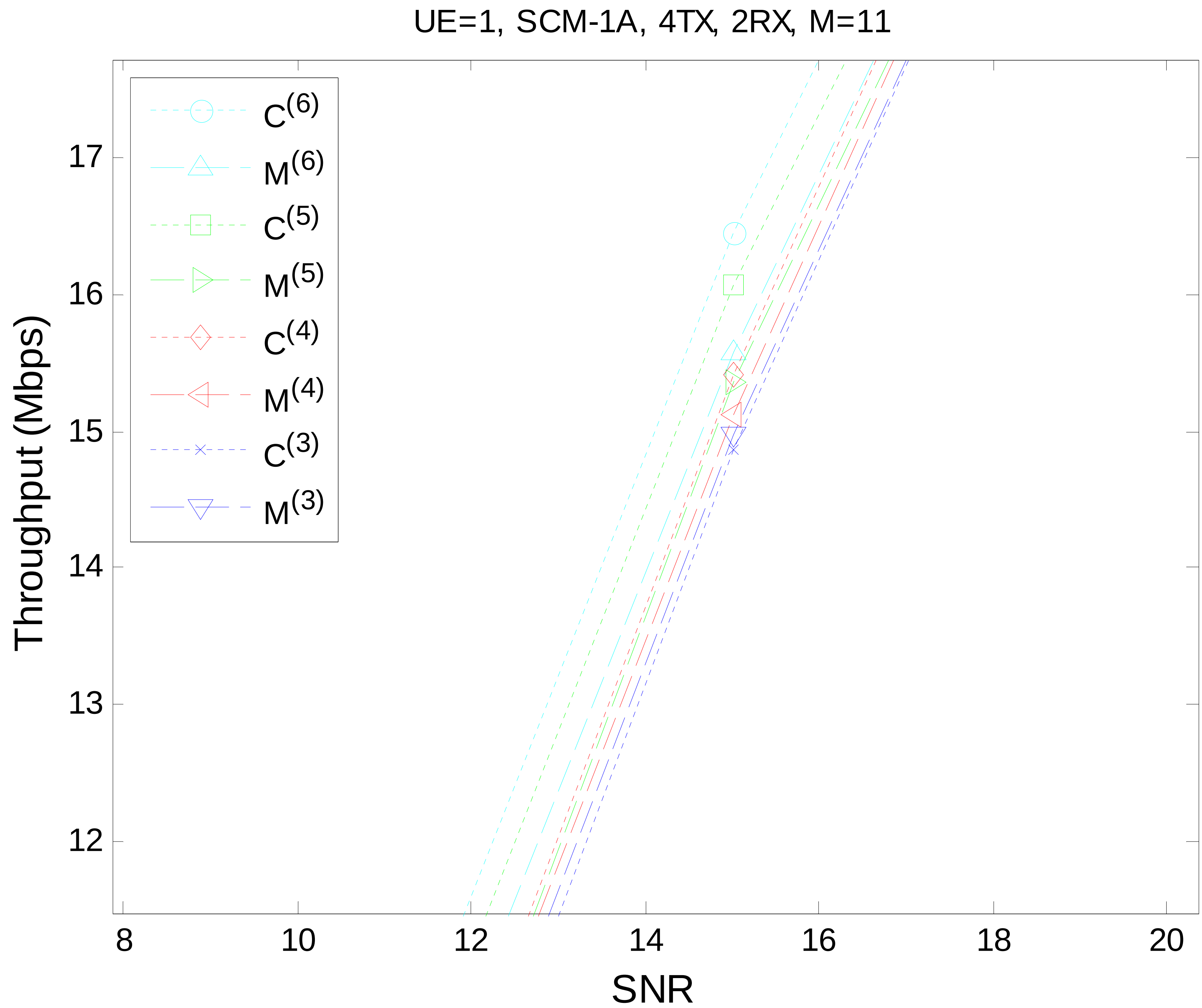

UE=1, SCM-1A, 4TX, 2RX, M=3
Throughput (Mbps)
SNR
0
1
2
3
4
5
6
7
-5
0
5
10
15
20
25
C(6)
M(6)
C(5)
M(5)
C(4)
M(4)
C(3)
M(3)

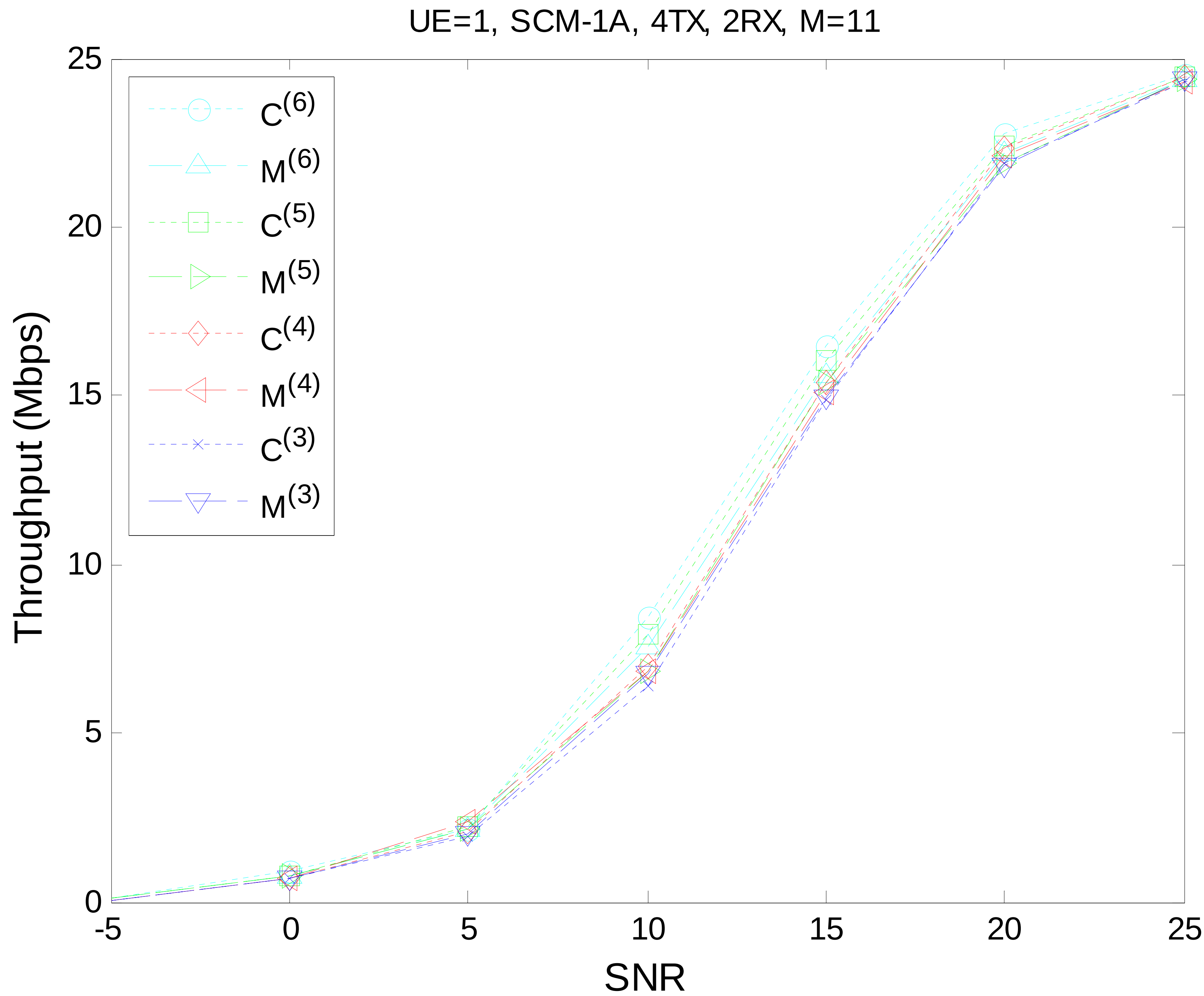


UE=1, SCM-1A, 4TX, 2RX, M=3
Throughput (Mbps)
SNR
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
10
12
14
16
18
20
$C^{(6)}$
$M^{(6)}$
$C^{(5)}$
$M^{(5)}$
$C^{(4)}$
$M^{(4)}$
$C^{(3)}$
$M^{(3)}$

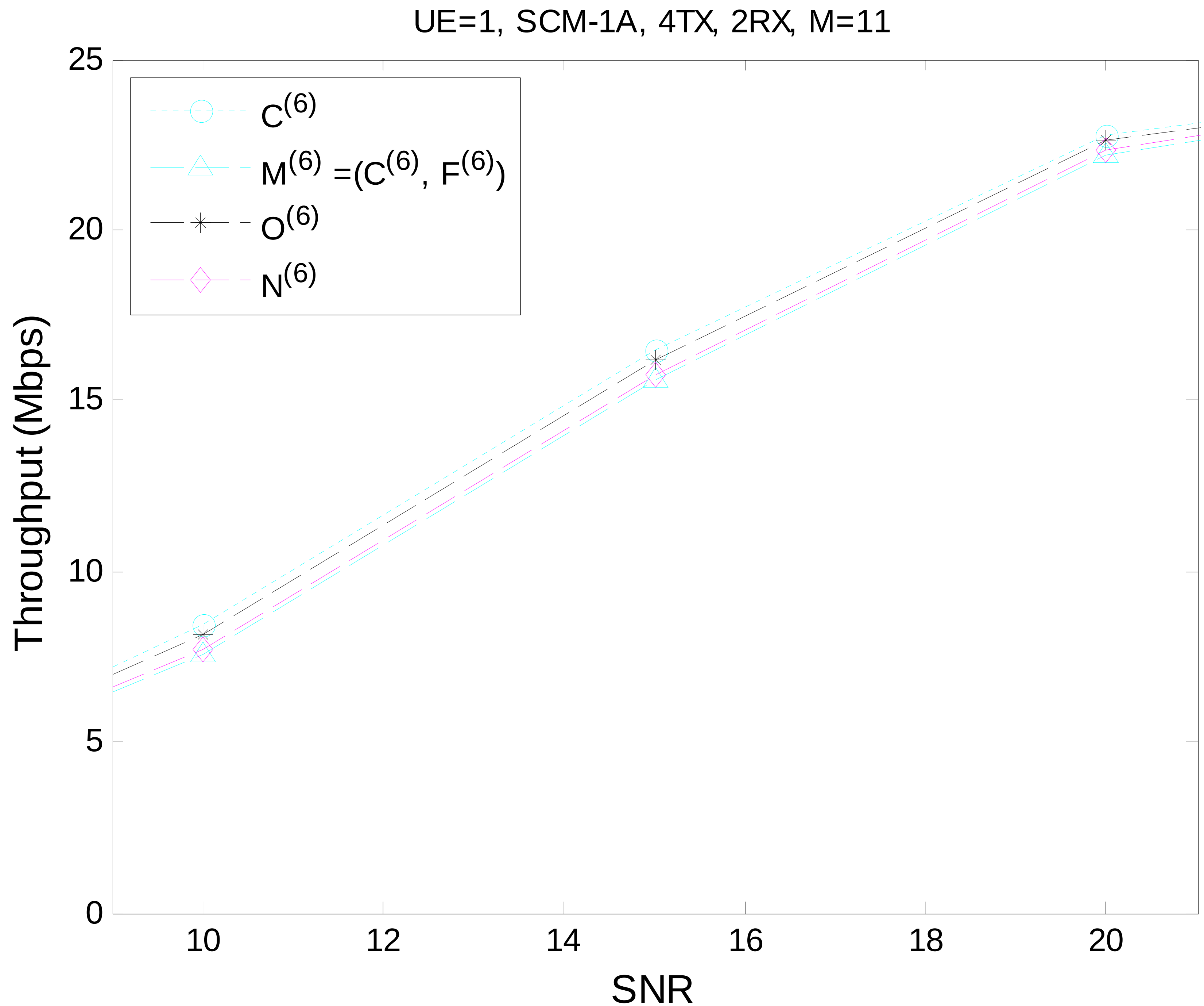


UE=1, SCM-1A, 4TX, 2RX, M=7
Throughput (Mbps)
SNR
11.5
11
10.5
10
9.5
9
8.5
8
10
12
14
16
18
20
C(6)
M(6)
C(5)
M(5)
C(4)
M(4)
C(3)
M(3)


UE=1, SCM-1A, 4TX, 2RX, M=11
Throughput (Mbps)
SNR
C(6)
M(6)
C(5)
M(5)
C(4)
M(4)
C(3)
M(3)
12
13
14
15
16
17
8
10
12
14
16
18
20



UE=1, SCM-1A, 4TX, 2RX, M=11
Throughput (Mbps)
SNR
-5
0
5
10
15
20
25
C(6)
M(6)
C(5)
M(5)
C(4)
M(4)
C(3)
M(3)



UE=1, SCM-1A, 4TX, 2RX, M=11
25
20
15
10
5
0
10
12
14
16
18
20
SNR
Throughput (Mbps)
C(6)
M(6) =(C(6), F(6))
O(6)
N(6)

Conclusion

- In comparison to Single-resolution codebook, the Multi-resolution codebook
  - Achieves the same performance using less feedback bits
  - Achieves better performance with the same feedback bits
  - Has about the same computational complexity and slightly higher memory requirement