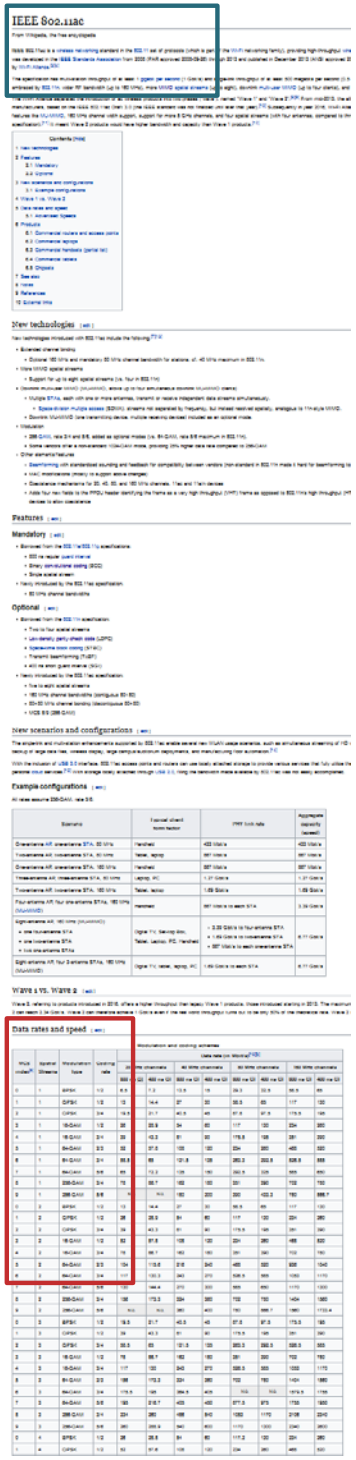
Principles of Communications
EES 351

Asst. Prof. Dr. Prapun Suksompong

prapun@siit.tu.ac.th

4.8 QAM



IEEE 802.11ac

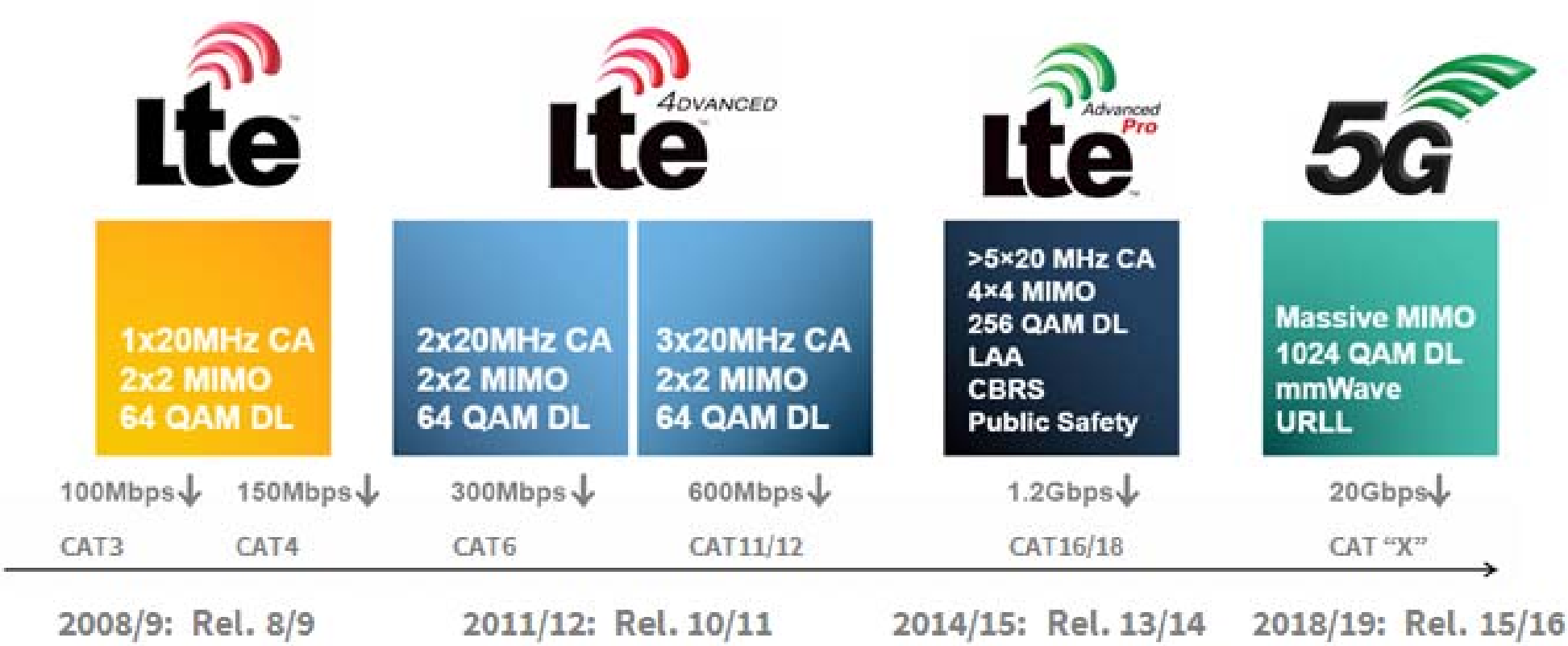
From Wikipedia, the free encyclopedia

IEEE 802.11ac is a wireless networking standard in the 80
The standard was developed in the IEEE Standards Assoc
retroactively labelled as **Wi-Fi 5** by Wi-Fi Alliance.[3][4]

Data rates and speed [edit]

MCS index[a]	Spatial Streams	Modulation type	Coding rate
0	1	BPSK	1/2
1	1	QPSK	1/2
2	1	QPSK	3/4
3	1	16-QAM	1/2
4	1	16-QAM	3/4
5	1	64-QAM	2/3
6	1	64-QAM	3/4
7	1	64-QAM	5/6
8	1	256-QAM	3/4
9	1	256-QAM	5/6
0	2	BPSK	1/2
1	2	QPSK	1/2
2	2	QPSK	3/4
3	2	16-QAM	1/2
4	2	16-QAM	3/4
5	2	64-QAM	2/3
6	2	64-QAM	3/4
7	2	64-QAM	5/6
8	2	256-QAM	3/4
9	2	256-QAM	5/6

LTE


Lte
4dvanced
Lte
Advanced Pro
Lte
5G
1x20MHz CA
2x2 MIMO
64 QAM DL
2x20MHz CA
2x2 MIMO
64 QAM DL
3x20MHz CA
2x2 MIMO
64 QAM DL
>5×20 MHz CA
4×4 MIMO
256 QAM DL
LAA
CBRS
Public Safety
Massive MIMO
1024 QAM DL
mmWave
URLL
100Mbps
150Mbps
300Mbps
600Mbps
1.2Gbps
20Gbps
CAT3
CAT4
CAT6
CAT11/12
CAT16/18
CAT "X"
2008/9: Rel. 8/9
2011/12: Rel. 10/11
2014/15: Rel. 13/14
2018/19: Rel. 15/16

Three Forms of QAM

Emphasize that there are two messages

1 $x_{\text{QAM}}(t) = 3\sqrt{2}\cos(2\pi f_c t) + 4\sqrt{2}\sin(2\pi f_c t)$

$\Leftrightarrow 3\sqrt{2}\angle 0° + 4\sqrt{2}\angle -90° \approx 5\sqrt{2}\angle -53°$

2 $\Leftrightarrow 5\sqrt{2}\cos\left(2\pi f_c t + (-53°)\right)$

Emphasize that the messages are embedded in both amplitude and phase of the carrier

$e^{jx} = \cos(x) + j\sin(x)$ $\quad -je^{jx} = -j\cos(x) + \sin(x)$

$\cos(x) = \text{Re}\{e^{jx}\}$ $\quad \sin(x) = \text{Re}\{-je^{jx}\}$

3 $x_{\text{QAM}}(t) = 3\sqrt{2}\text{Re}\{e^{j2\pi f_c t}\} + 4\sqrt{2}\text{Re}\{-je^{j2\pi f_c t}\}$

$= \sqrt{2}\text{Re}\{(3-4j)e^{j2\pi f_c t}\}$

Emphasize the use of the combined complex-valued representation of the two messages.

Three Forms of QAM

Emphasize that there are two messages

1 $x_{\text{QAM}}(t) = m_1(t)\sqrt{2}\cos(2\pi f_c t) + m_2(t)\sqrt{2}\sin(2\pi f_c t)$

$\Leftrightarrow m_1(t)\sqrt{2}\angle 0° + m_1(t)\sqrt{2}\angle -90°$

$= E(t)\sqrt{2}\angle\phi(t)$

2 $\Leftrightarrow \sqrt{2}E(t)\cos\left(2\pi f_c t + \phi(t)\right)$

Emphasize that the messages are embedded in both amplitude and phase of the carrier

$e^{jx} = \cos(x) + j\sin(x)$ $\quad -je^{jx} = -j\cos(x) + \sin(x)$

$\cos(x) = \text{Re}\{e^{jx}\}$ $\quad \sin(x) = \text{Re}\{-je^{jx}\}$

3 $x_{\text{QAM}}(t) = m_1(t)\sqrt{2}\text{Re}\{e^{j2\pi f_c t}\} + m_2(t)\sqrt{2}\text{Re}\{-je^{j2\pi f_c t}\}$

$= \sqrt{2}\text{Re}\{(m_1(t) - jm_2(t))e^{j2\pi f_c t}\}$

Emphasize the use of the combined complex-valued representation of the two messages.