



Radio Resource Management in Machine-to-Machine Communications

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IEEE COMMUNICATION SURVEYS & TUTORIAL, VOL. 20, NO. 1,
FIRST QUARTER 2018.



教育經歷：

2008-2012: 東北大學 本科

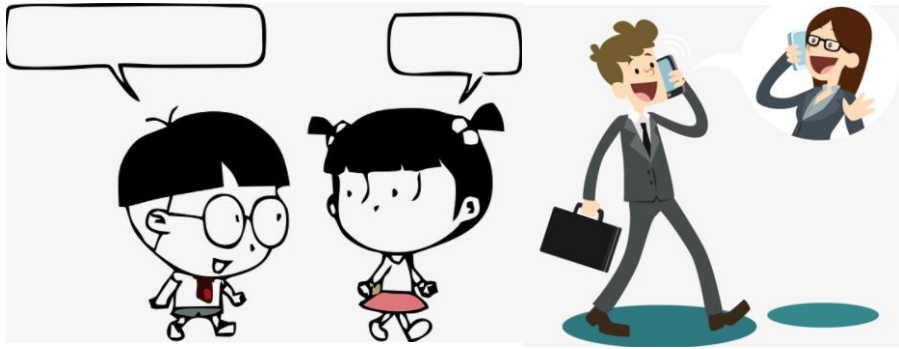
2012-2014: 國立成功大學 碩士 (指導教授: 楊竹星博士)

2014-至今: 國立成功大學 博士 (指導教授: 楊竹星博士, 共同指導教授: 陳曉華博士)

研究領域：

1. Machine-to-machine communications
2. Device-to-device communications

Human-to-Human

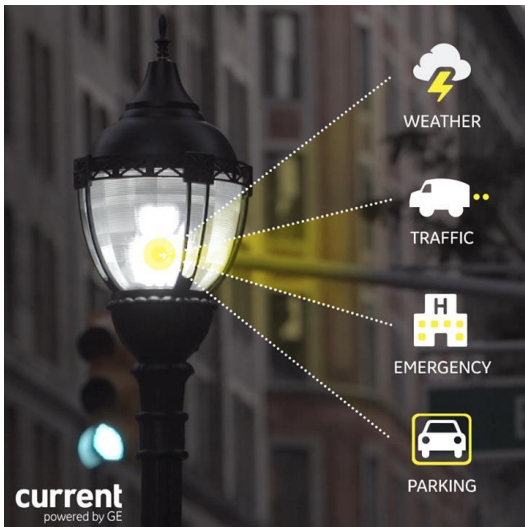


Human-to-Machine

Machine-to-Human

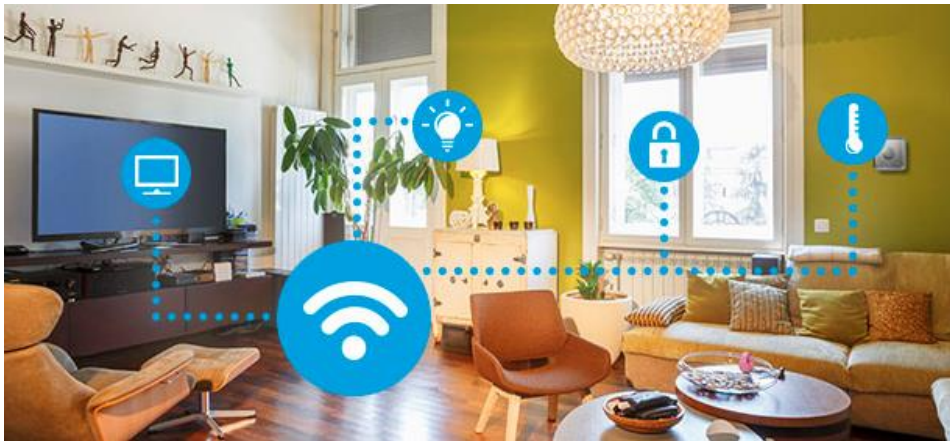


Machine-to-Machine = Internet-of-Things



Machine-to-Machine devices can communicate with each other directly without/with little human intervention.

↓
AI + IoT



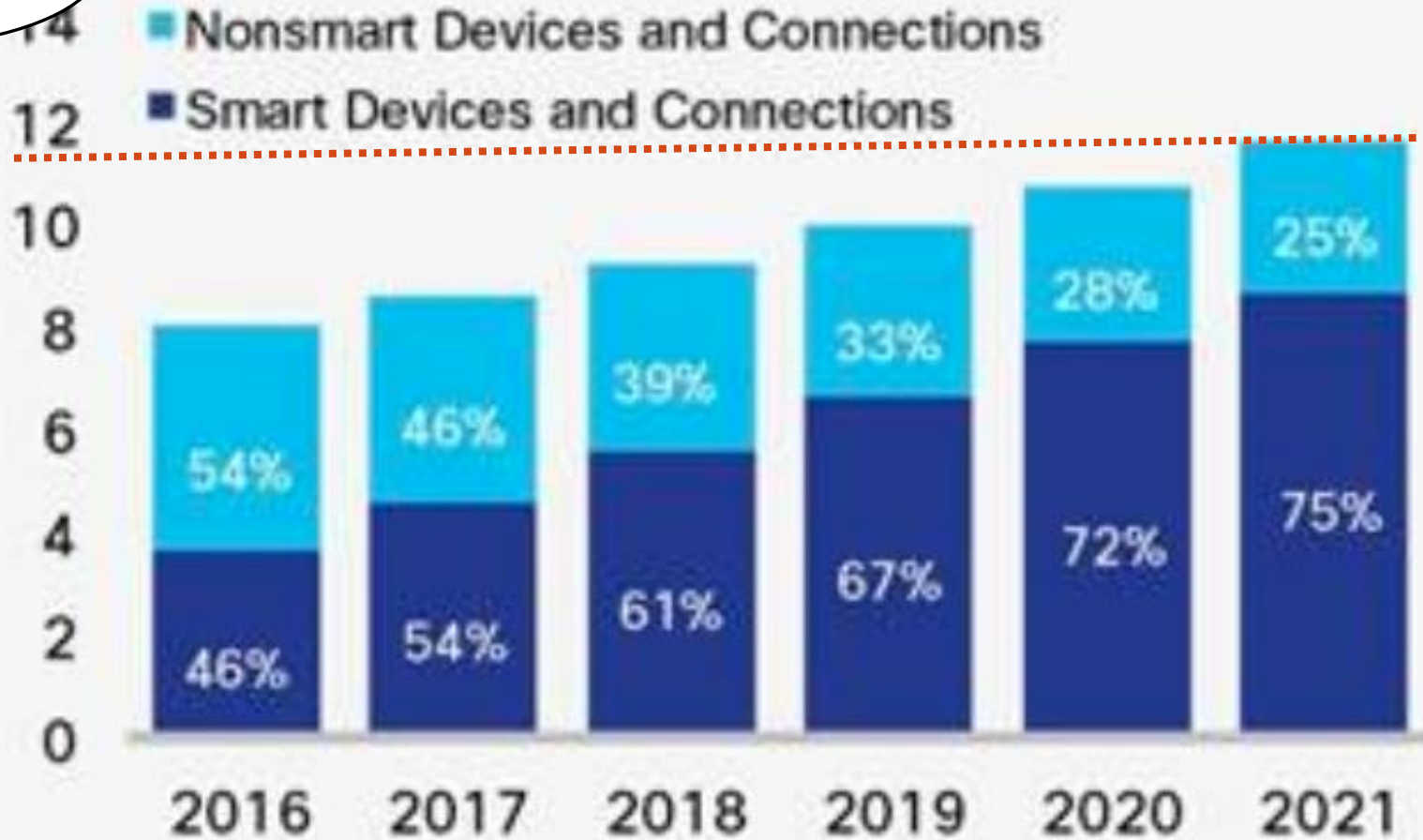
Cisco Global Mobile Traffic Growth Prediction



Cisco Global Mobile Connections Growth Prediction

Exceed human population

Billions of Devices



M2M features

Uplink dominate

Periodic

Small payload

Event triggering

Frequent

Traffic

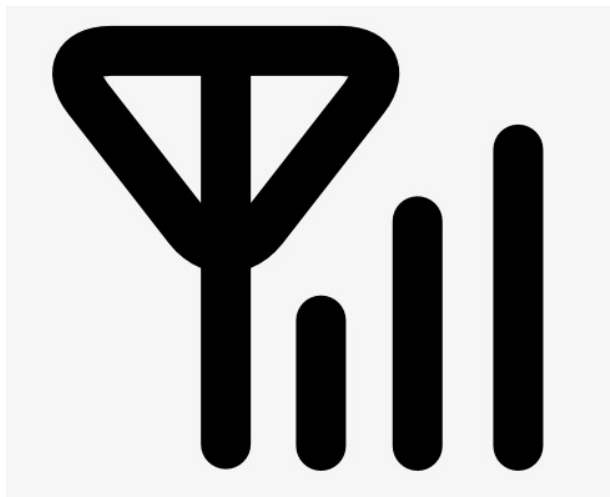
Energy sensitive

Power constrained

Energy

Massive number

Diverse QoS



Spectrum



Energy

bandwidth of the channel

Channel capacity in bits/s

$$C = B \log_2 (1 + S/N)$$

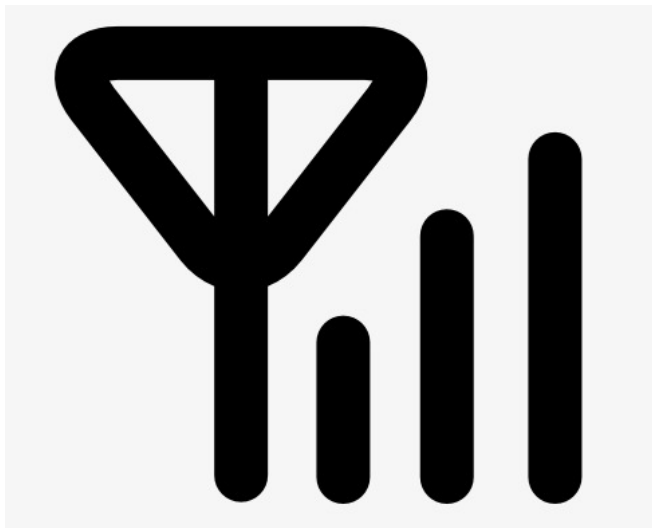
signal-to-noise ratio

Access IDs

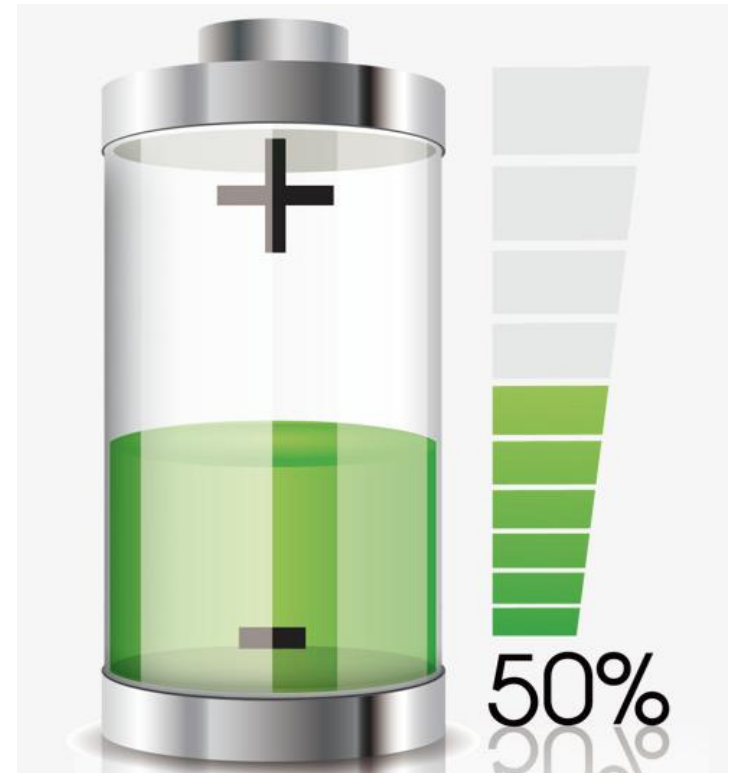




Massive connections
(1,000,000/km²)



Deep indoor environment



Several days VS 10 years

Uplink

Downlink

4G頻段

台灣之星

中華

國基

台灣之星

中華

國基

885 890 895 900 905 910 915

B1

B2

B3

930 935 940 945 950 955 960 MHz

B1

B2

B3

2G及3G頻段

亞太

遠傳
(北區)
台哥大
(區、南區)

遠傳
(北區)
台哥大
(區、南區)

4G頻段

台哥大

中華

遠傳

遠傳

中華

台哥大

中華

遠傳

遠傳

中華

1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770

C1

C2

C3

C4

C5

1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 MHz

C1

C2

C3

C4

C5

2G頻段

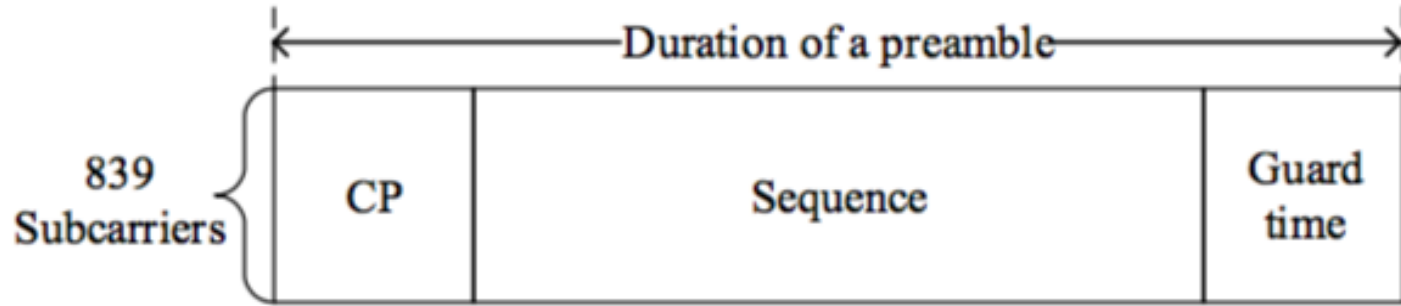
中華

台哥大

1710.1-1721.3 1721.3-1732.5 1732.5-1743.7 1743.7-1754.9

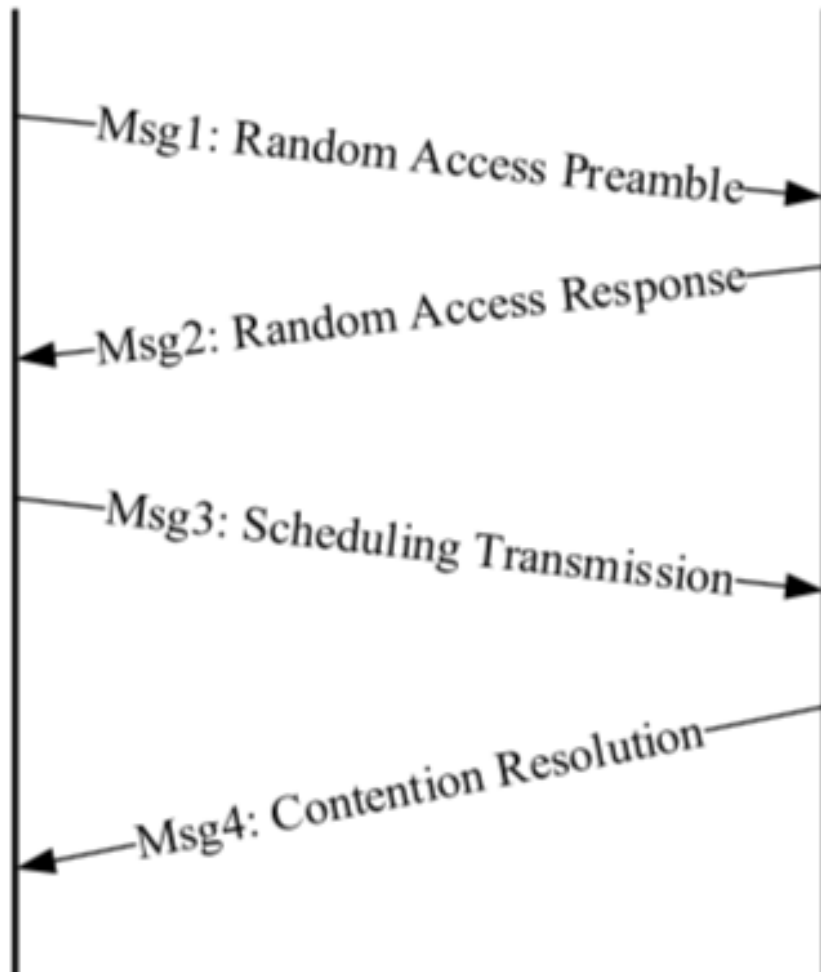
1805.1-1816.3 1816.3-1827.5 1827.5-1838.7 1838.7-1849.9

Preamble format



UE

eNB



Contention-based random access

64 preambles serve massive connections



Collision

Access class barring (ACB)

Separate new access classes:
barring probability + backoff counter

Configure



Dynamic access barring

Example 0 0 1 1 0 0 0 1 0 1

AC #	0	1	2	3	4	5	6	7	8	9	13	12	14	11	15
Priority Order	Ordinary										high	higher		highest	
AC Definition	Ordinary user WTRU ACs, include those HPLMN and those from visit-PLMN										Public Utilities	Security Services	Emergency Services	PLMN use	PLMN Staff
Permission Class Definition-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Permission Class Definition-2	1			2			3			4	5	6	7	8	

Extended access barring

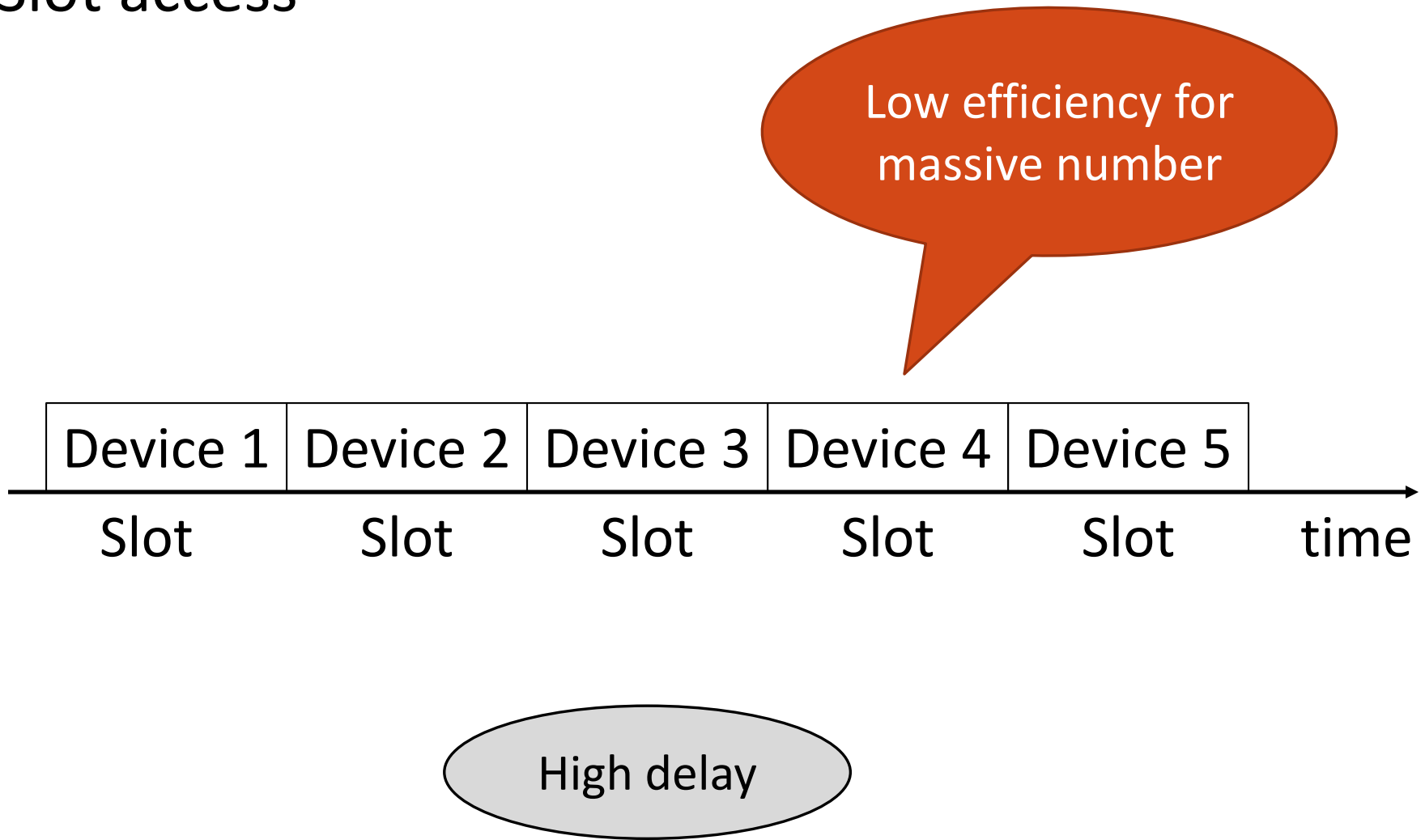
----Block delay-tolerant MTCDs

Bitmap: 0 0 0 0 1 1 1 0 1 0

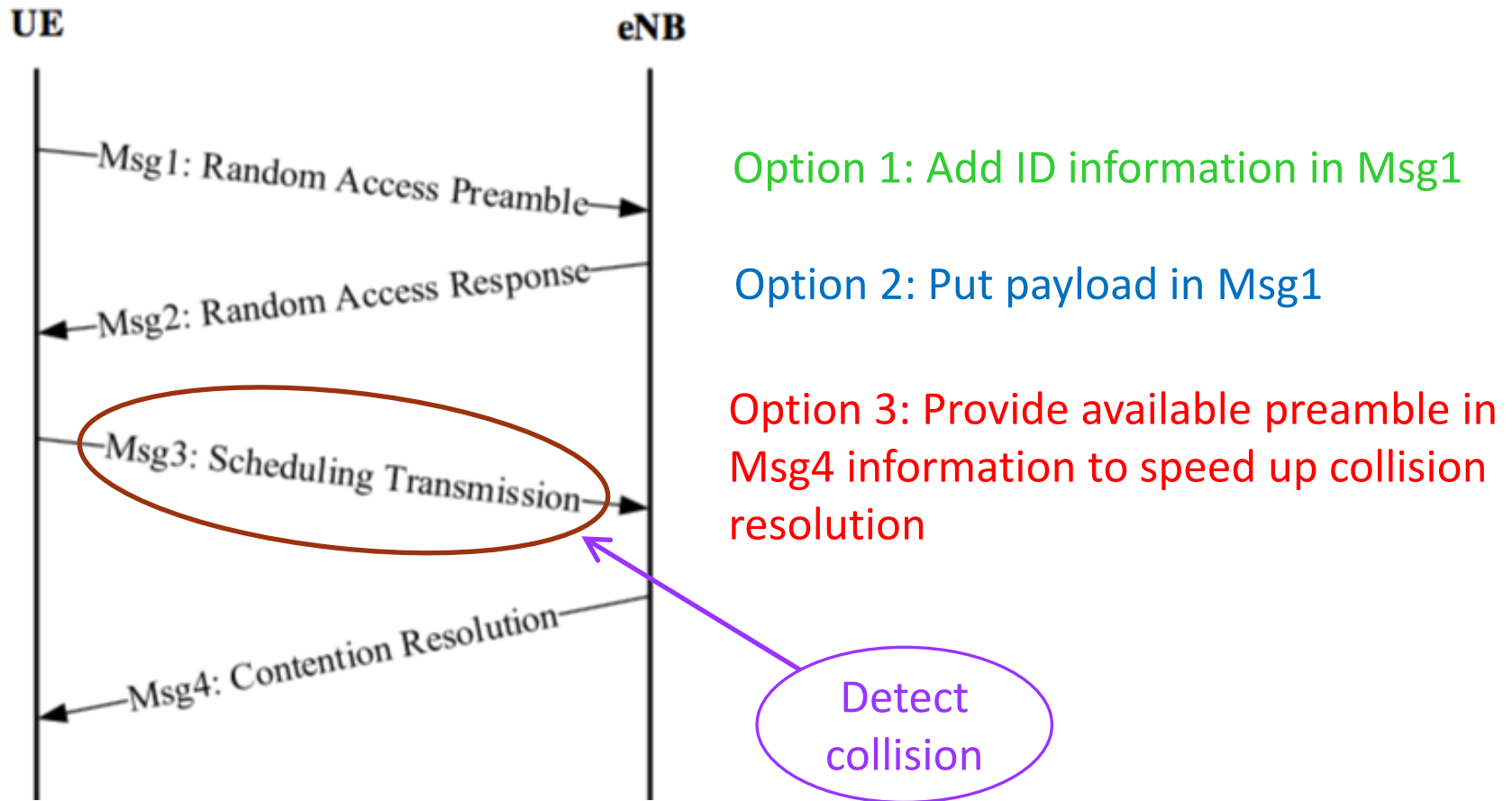


No additional
access classes

Slot access

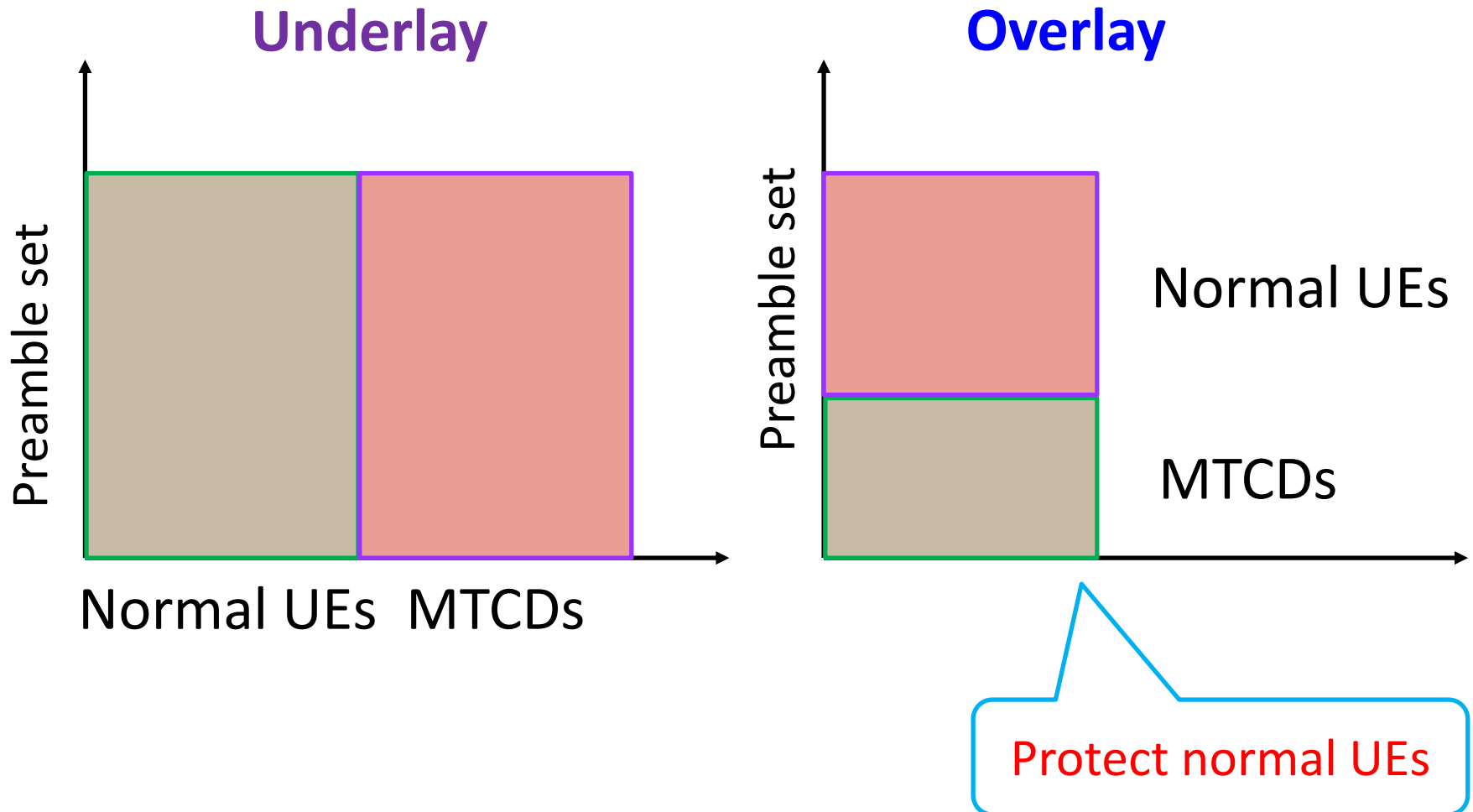


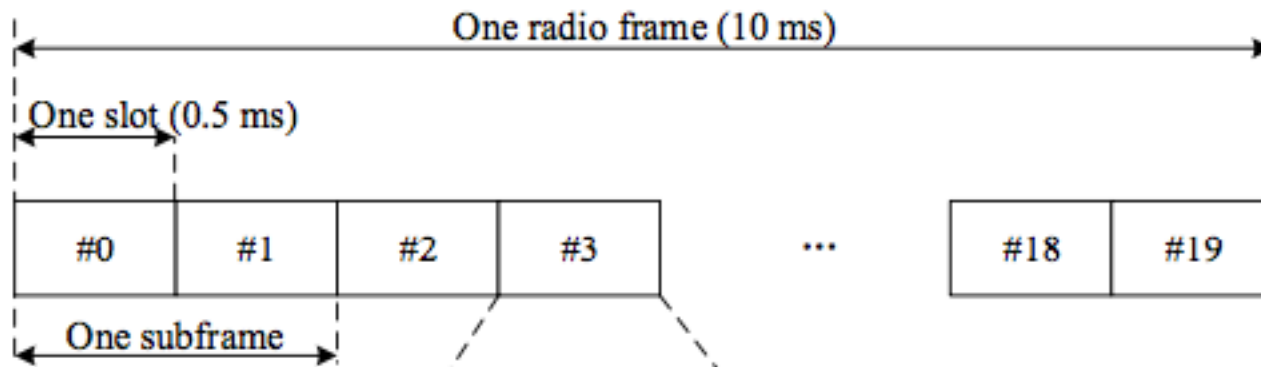
Random access procedure modification



Preambles and resource blocks allocation

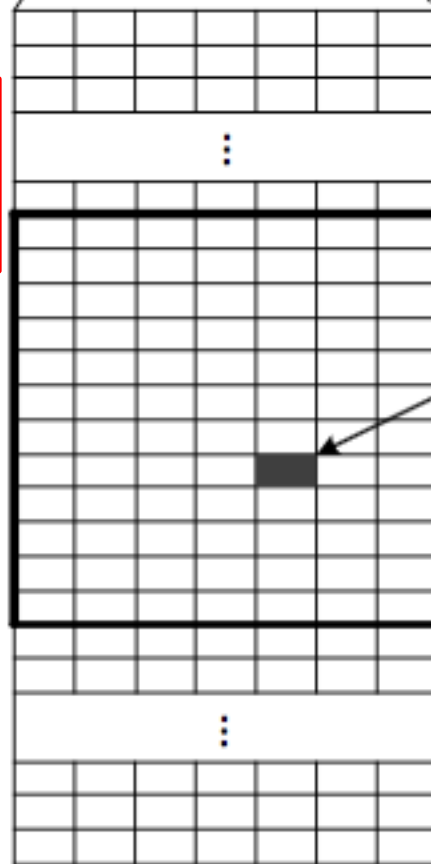
Option 1: Dynamic preamble allocation





12 subcarriers
each with 15 kHz

Subcarriers



Symbols

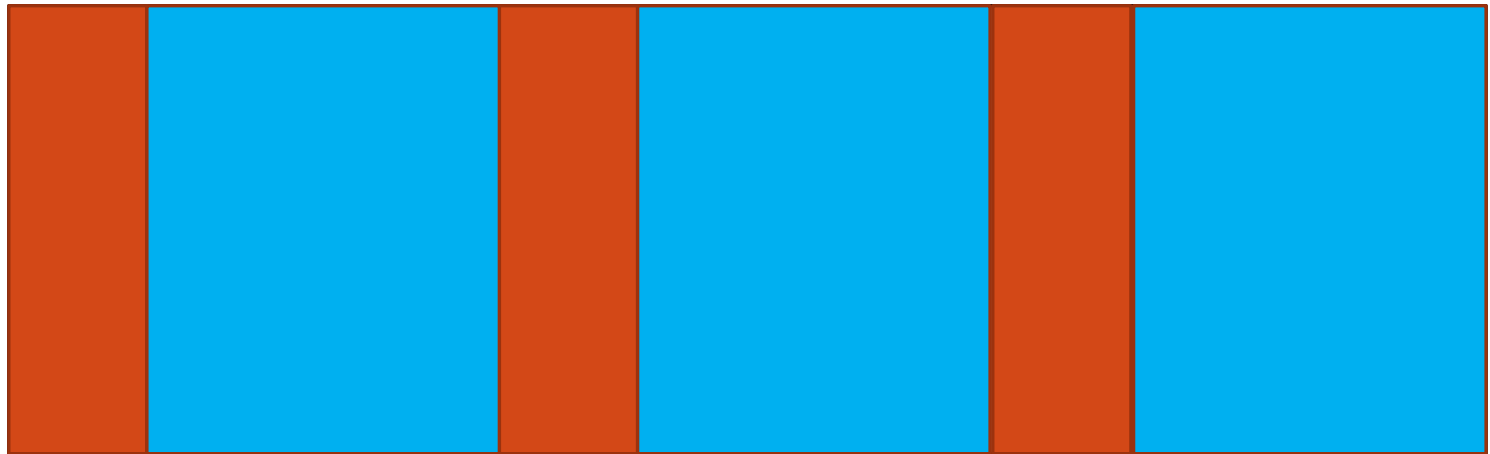
Resource block
(RB)

Resource
element (RE)

Basic resource
allocation unit

Preambles and resource blocks allocation

Option 2: Dynamic RBs allocation



Resource block pools



Physical random access channel (PRACH)

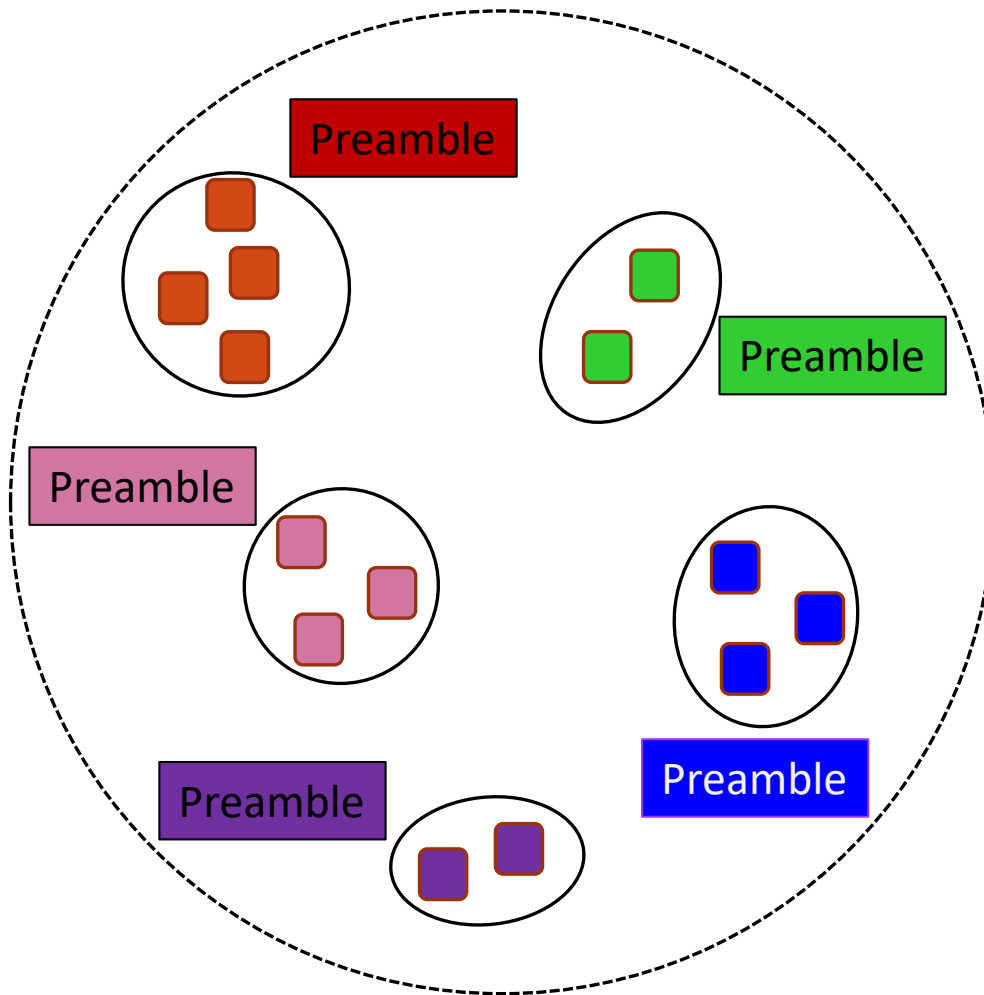


Physical uplink sharable channel (PUSCH)



Constant

Group-based random access

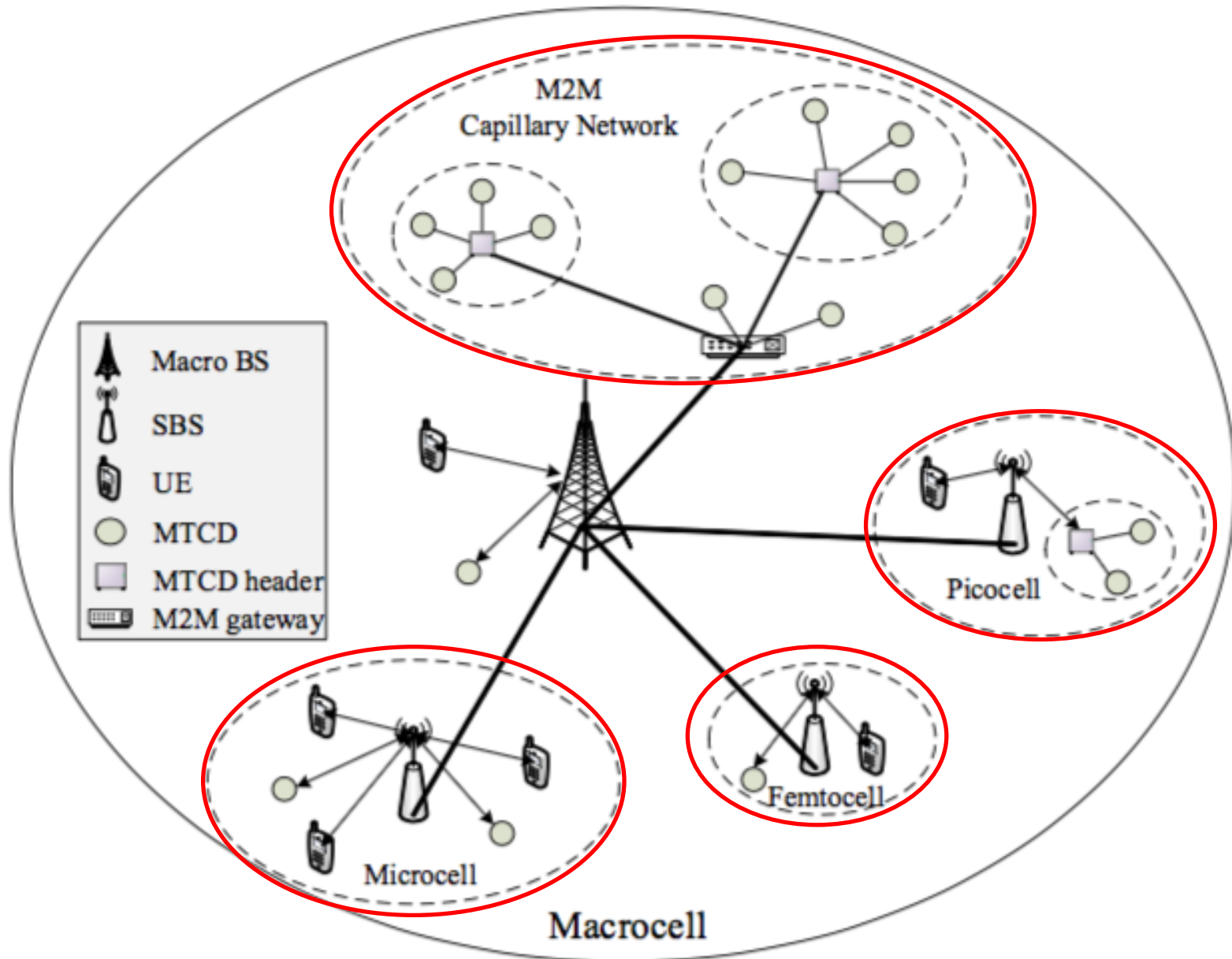


Option 1: Location-based

Option 2: QoS-based

Option 3: Machine learning

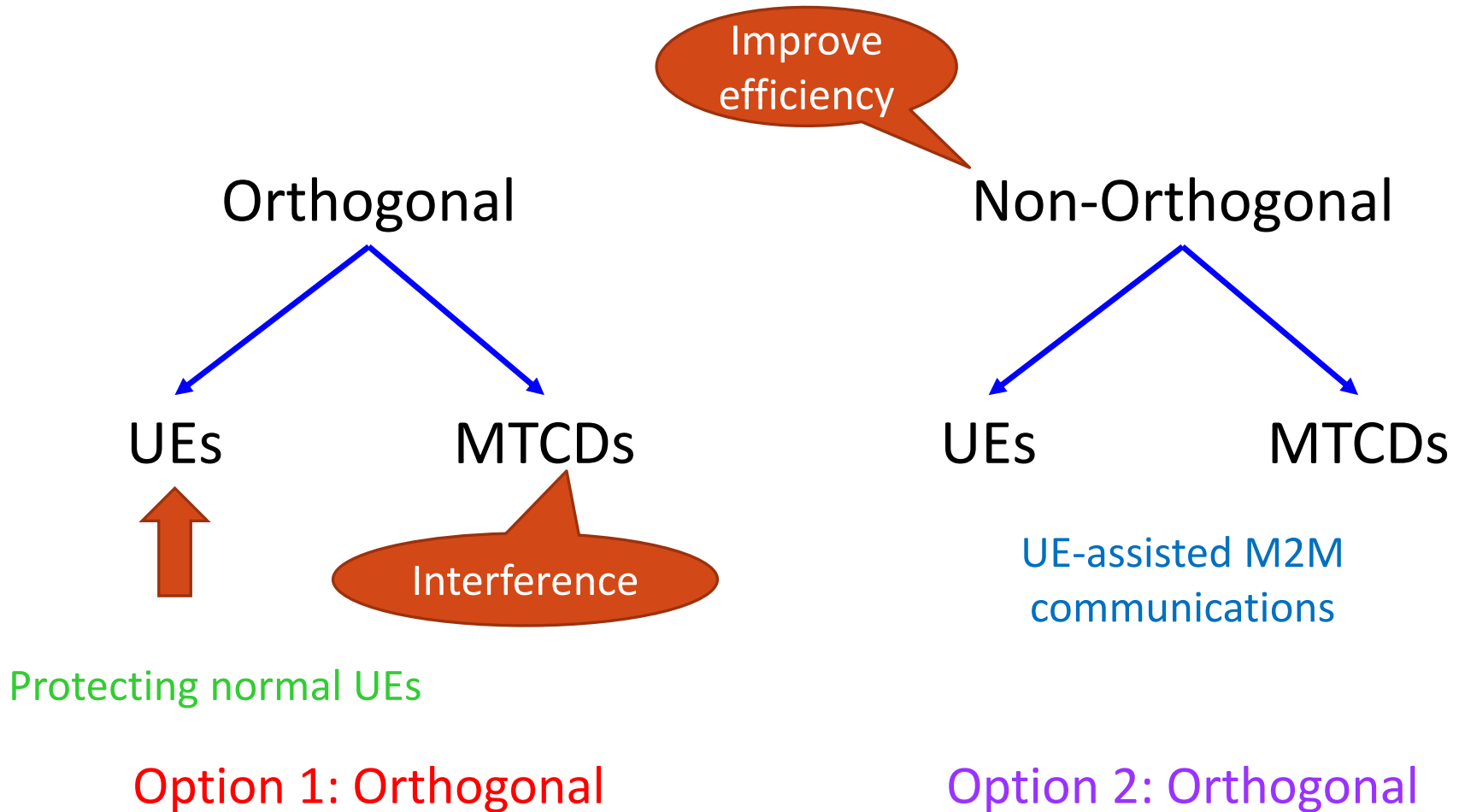
Small cells



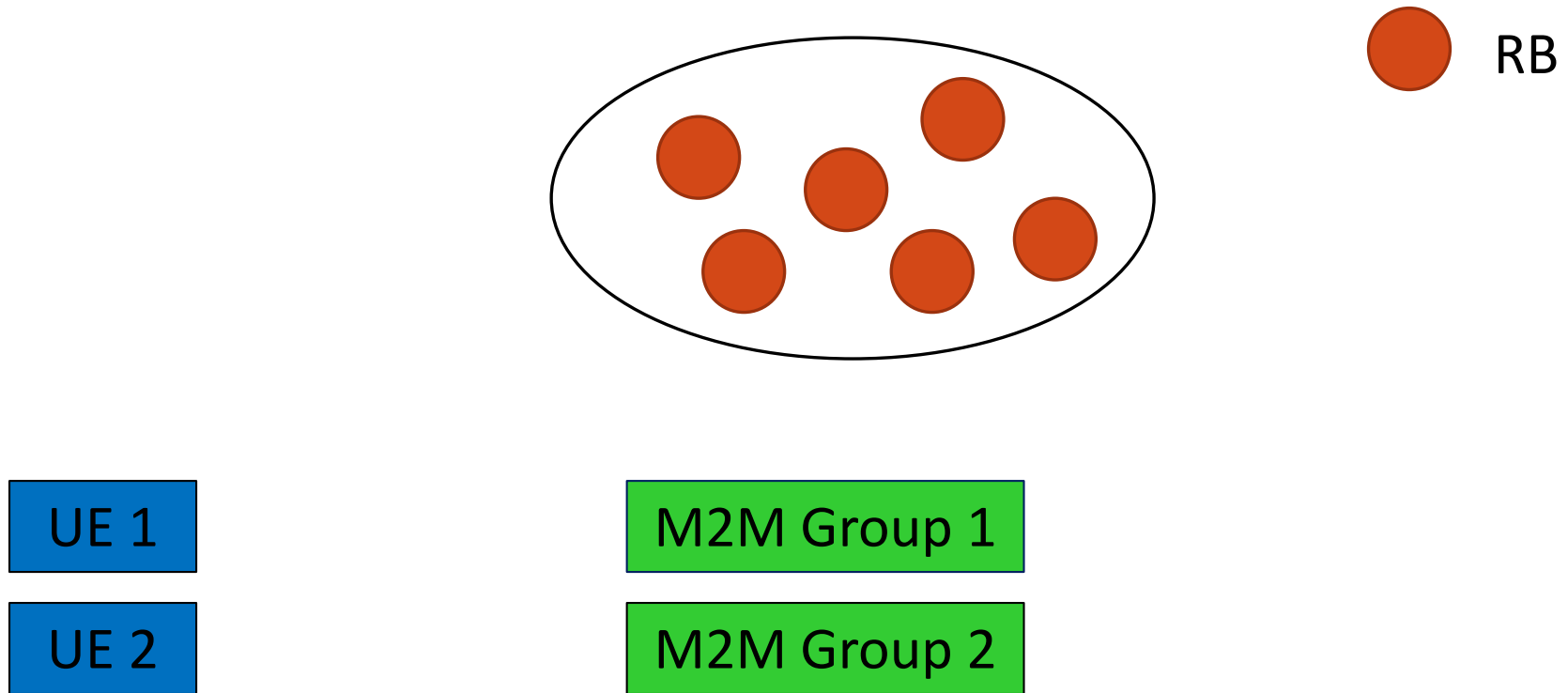
Small cells

Cell types	Typical cell radius	Power range	Use cases
Macrocell	> 1 km	20 W ~ 160 W	Cellular systems
Femtocell	10 m ~ 50 m	10 mW ~ 200 mW	Home, small offices
Picocell	100 m ~ 300 m	250 mW ~ > 2 W	Buildings
Microcell	250 m ~ 1 km	2 W ~ 20 W	Shopping mall, Stadium

Orthogonal and non-orthogonal resource allocation



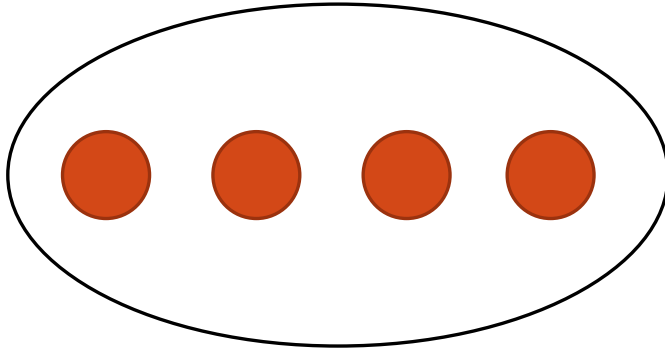
Resource pools



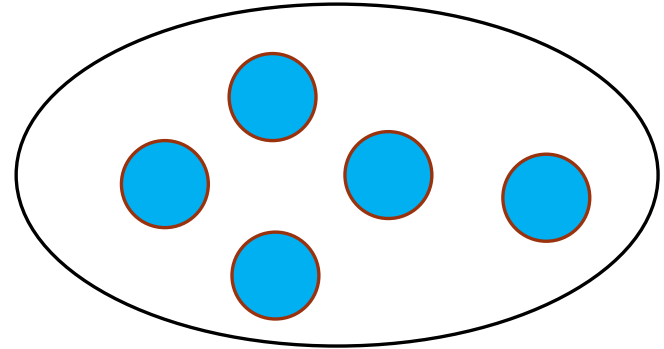
Case 1: M2M/H2H coexistence

Resource pools

Pre-allocated pool



Common pool



M2M
Group 1

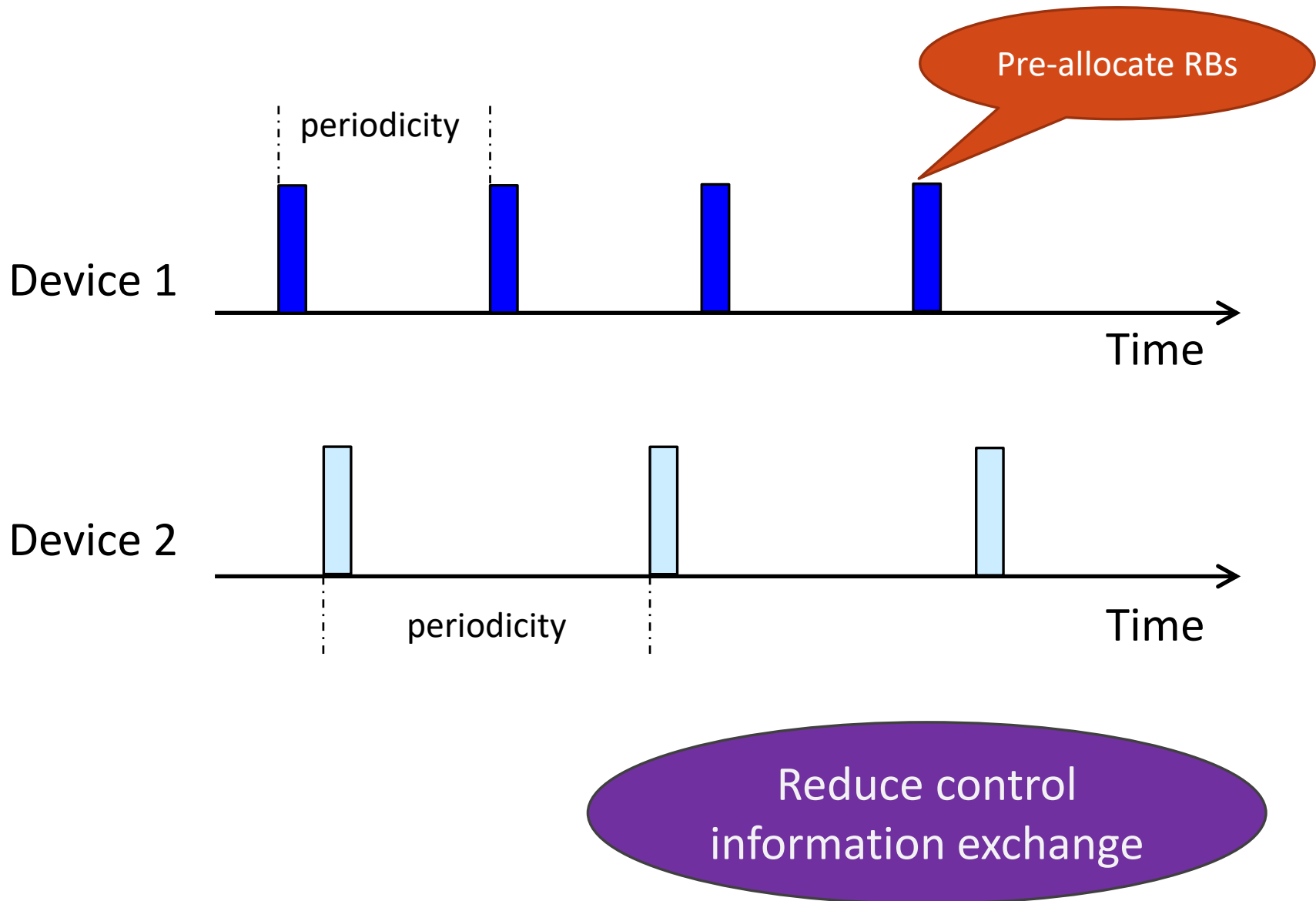
M2M
Group 2

M2M
Group 3

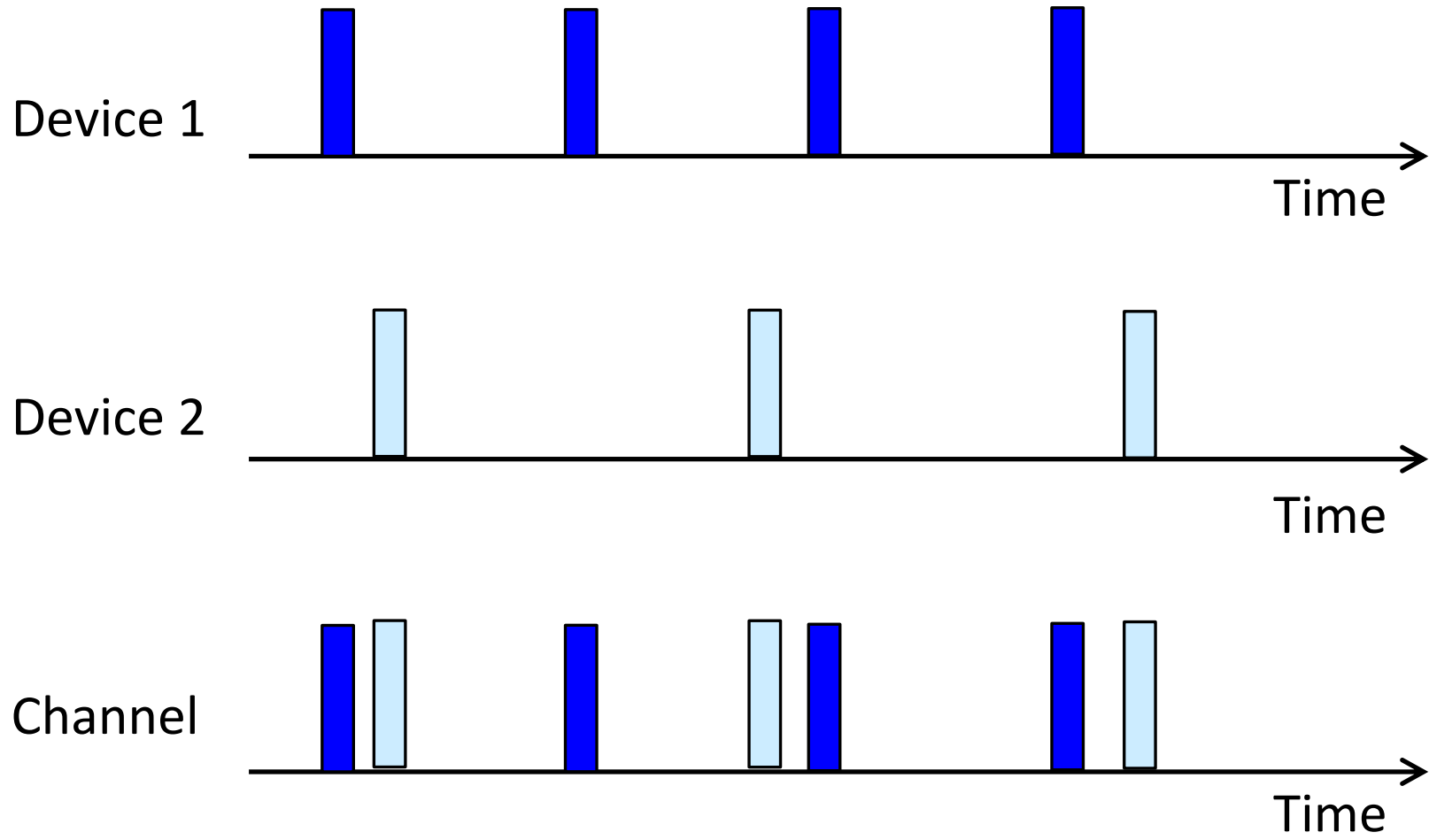
M2M
Group 4

Case 2: M2M only

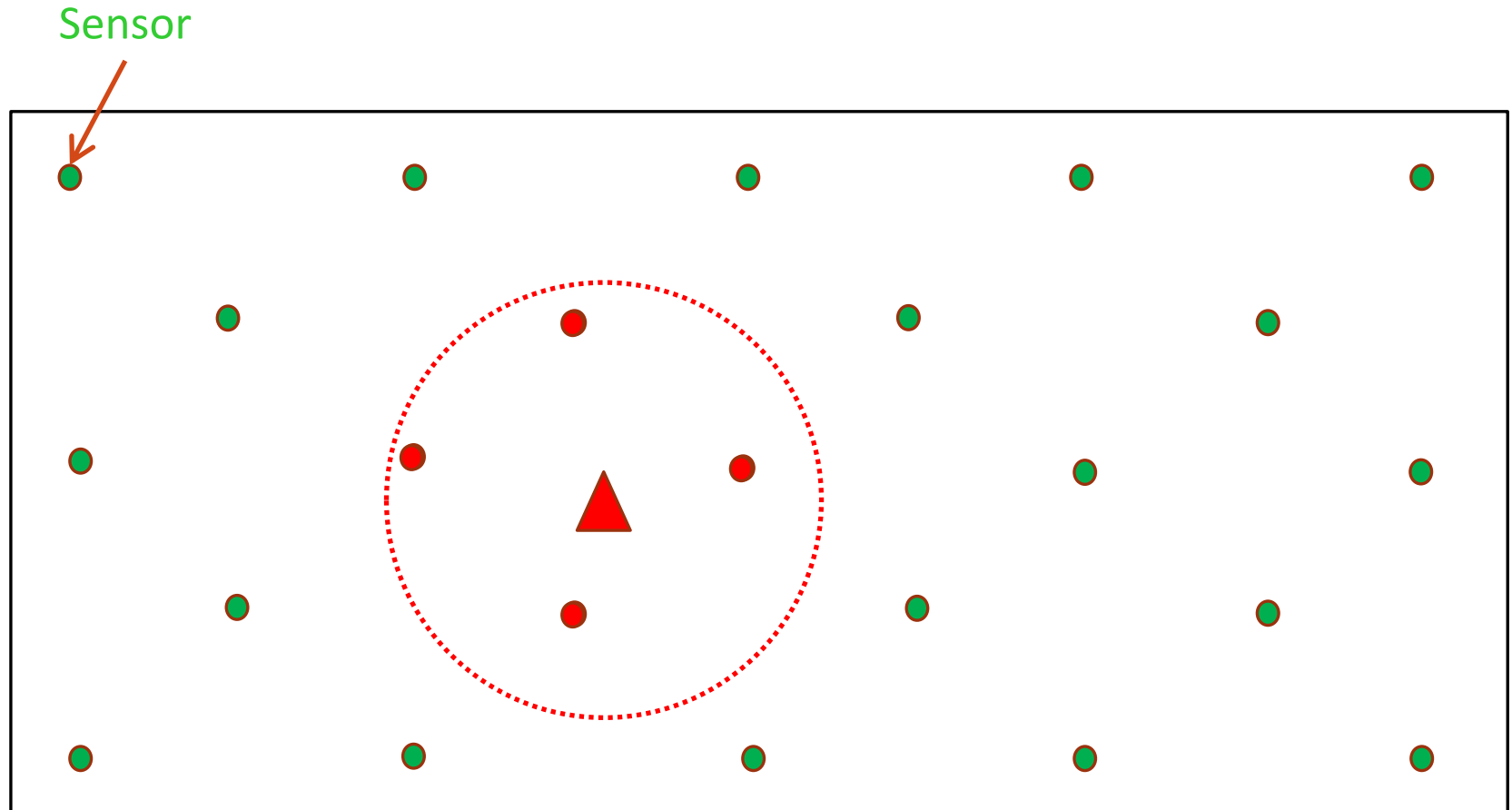
Semi-persistent resource allocation



Multiplexing

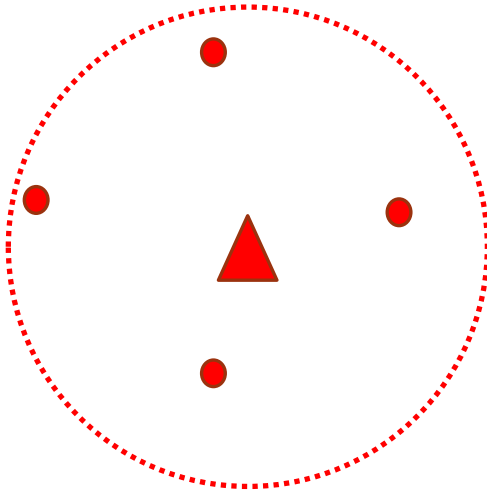


Predictive resource allocation

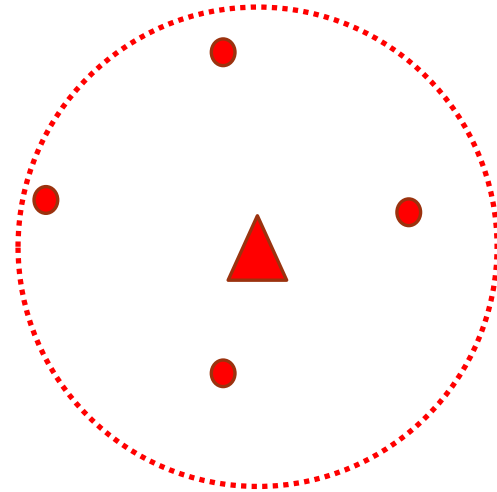


Fire alarming in farms

Predictive resource allocation

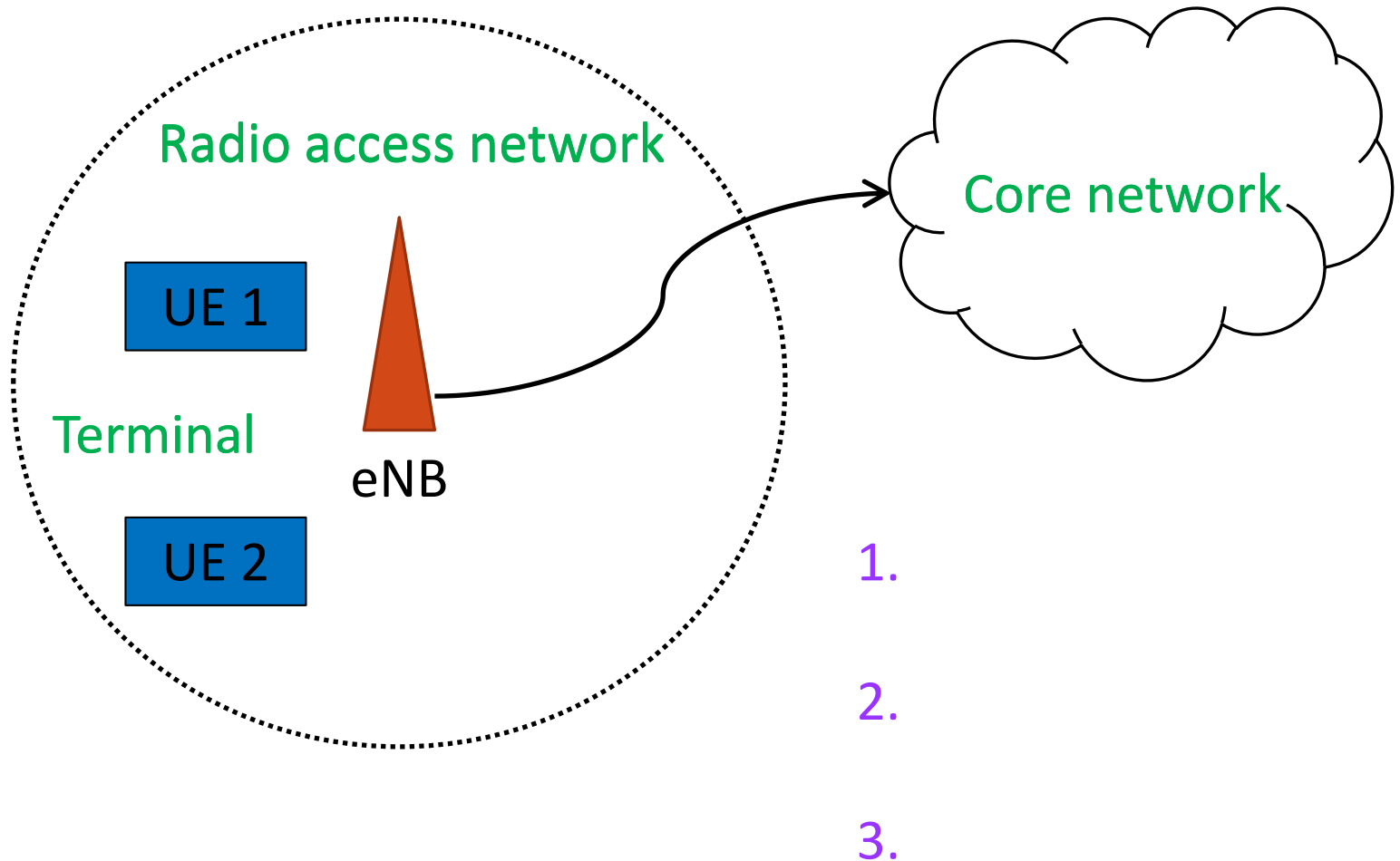


Resource allocation
without prediction

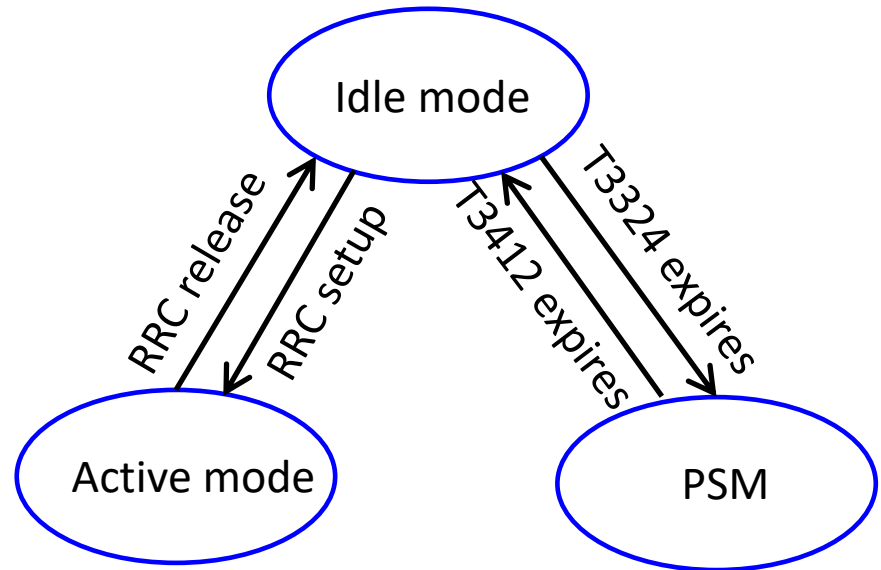
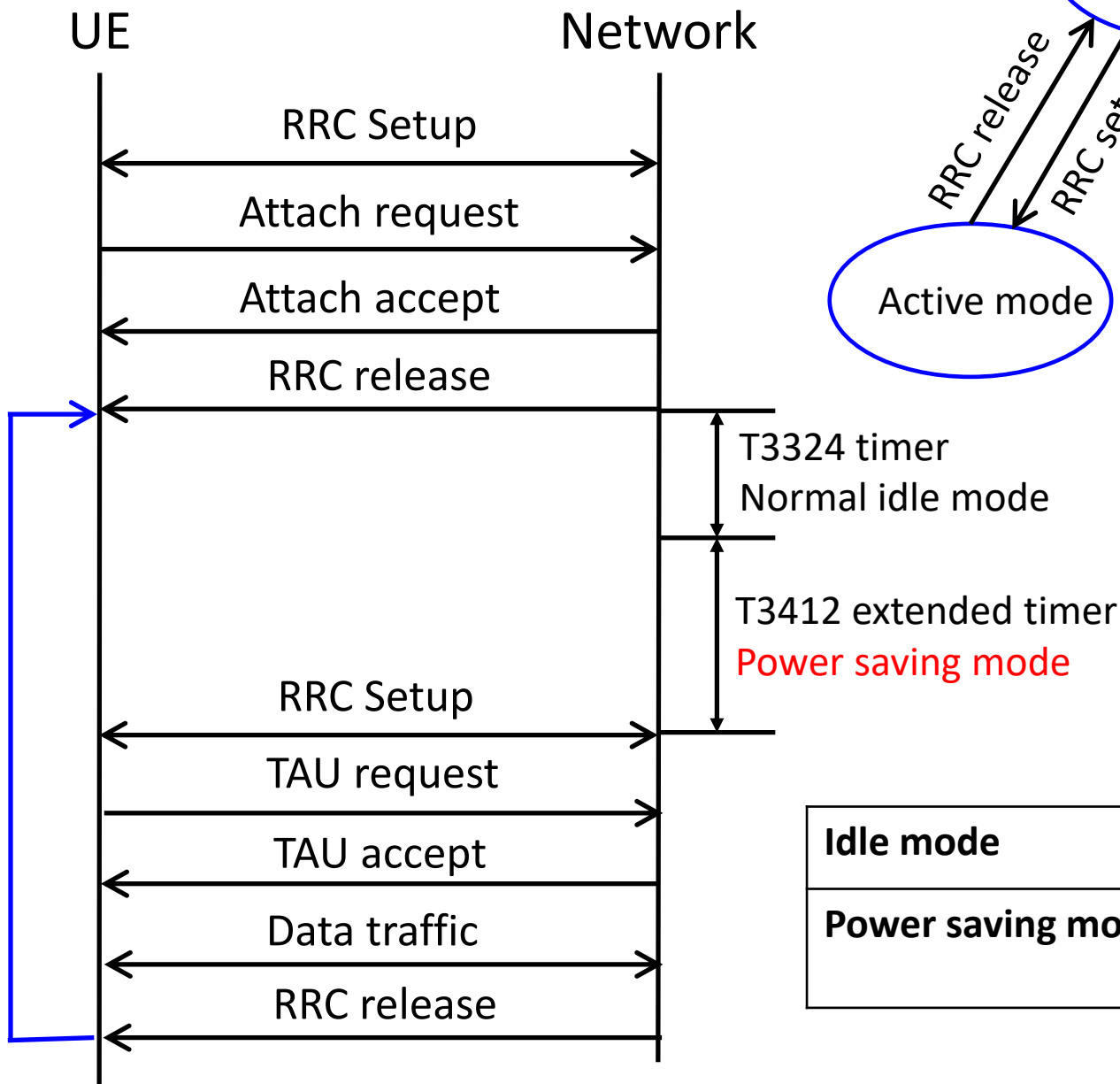


Predictive Resource
allocation

Energy management

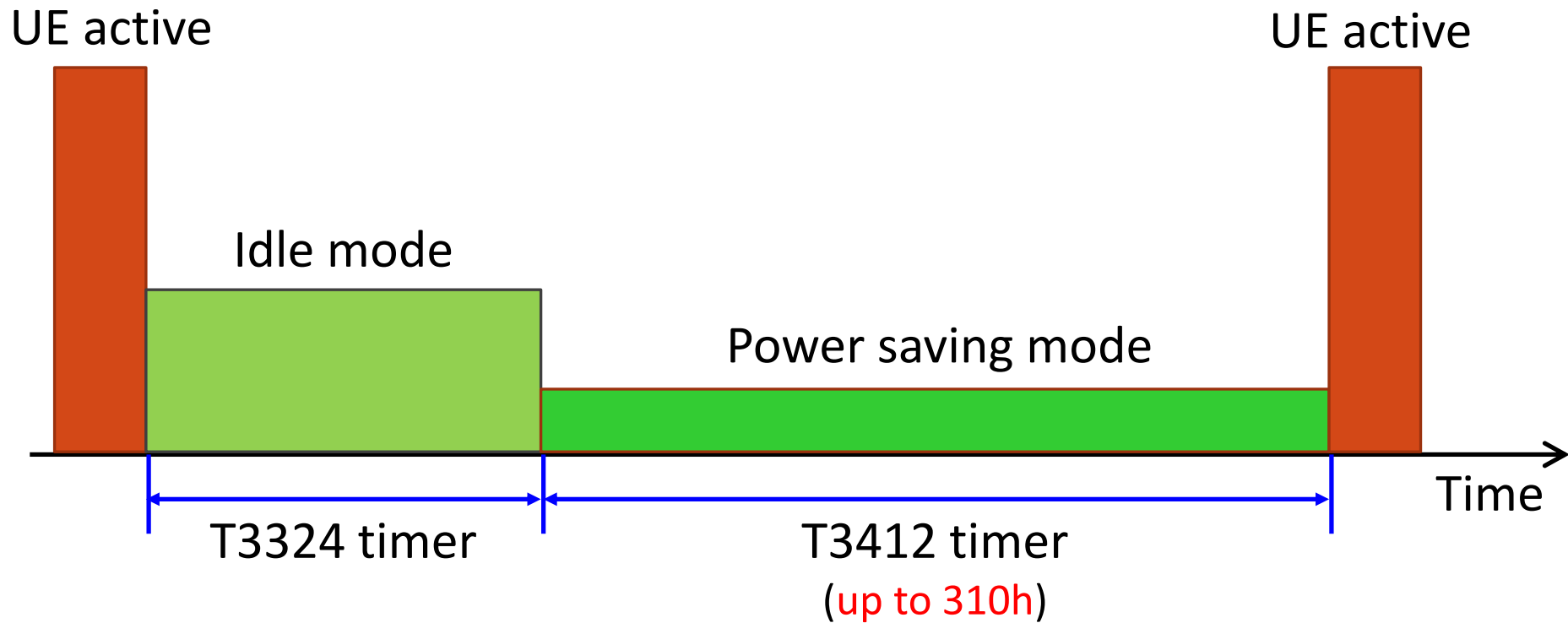


Power saving mode

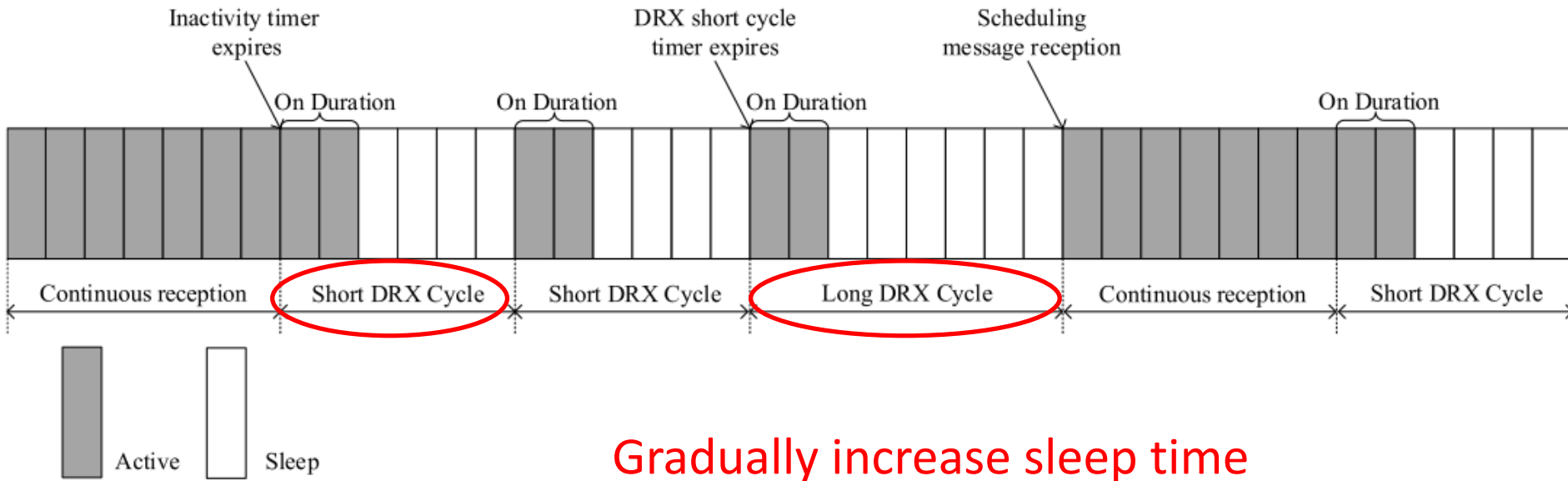


Idle mode	Monitor paging
Power saving mode	No paging Turn off functions

Power saving mode

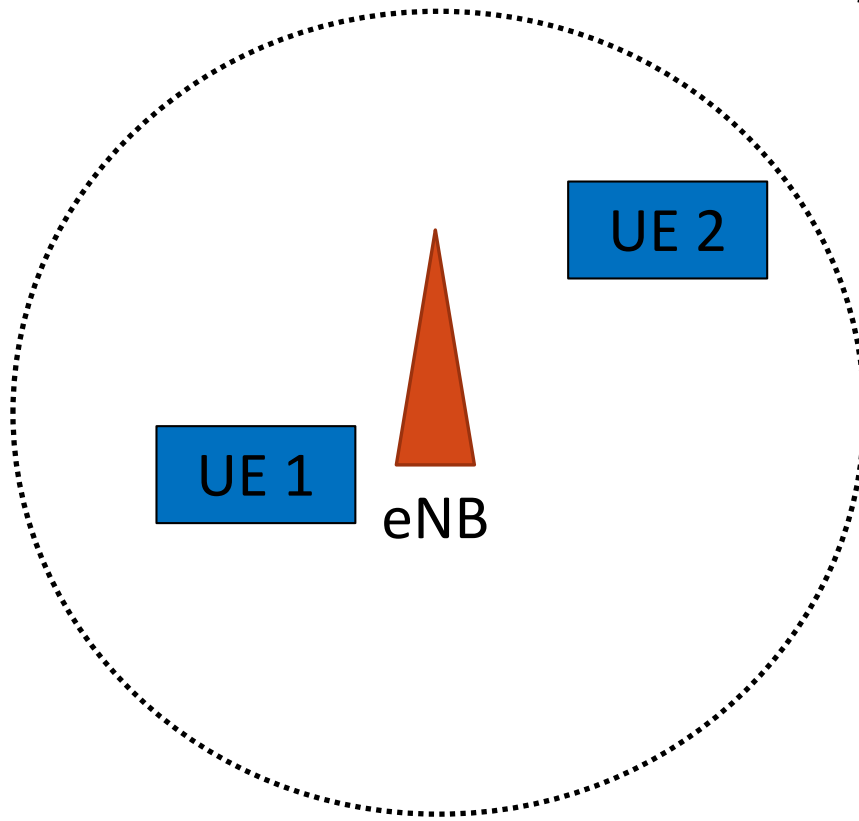


Discontinuous reception (DRX)



eDRX: further extend the DRX cycle for infrequent traffic

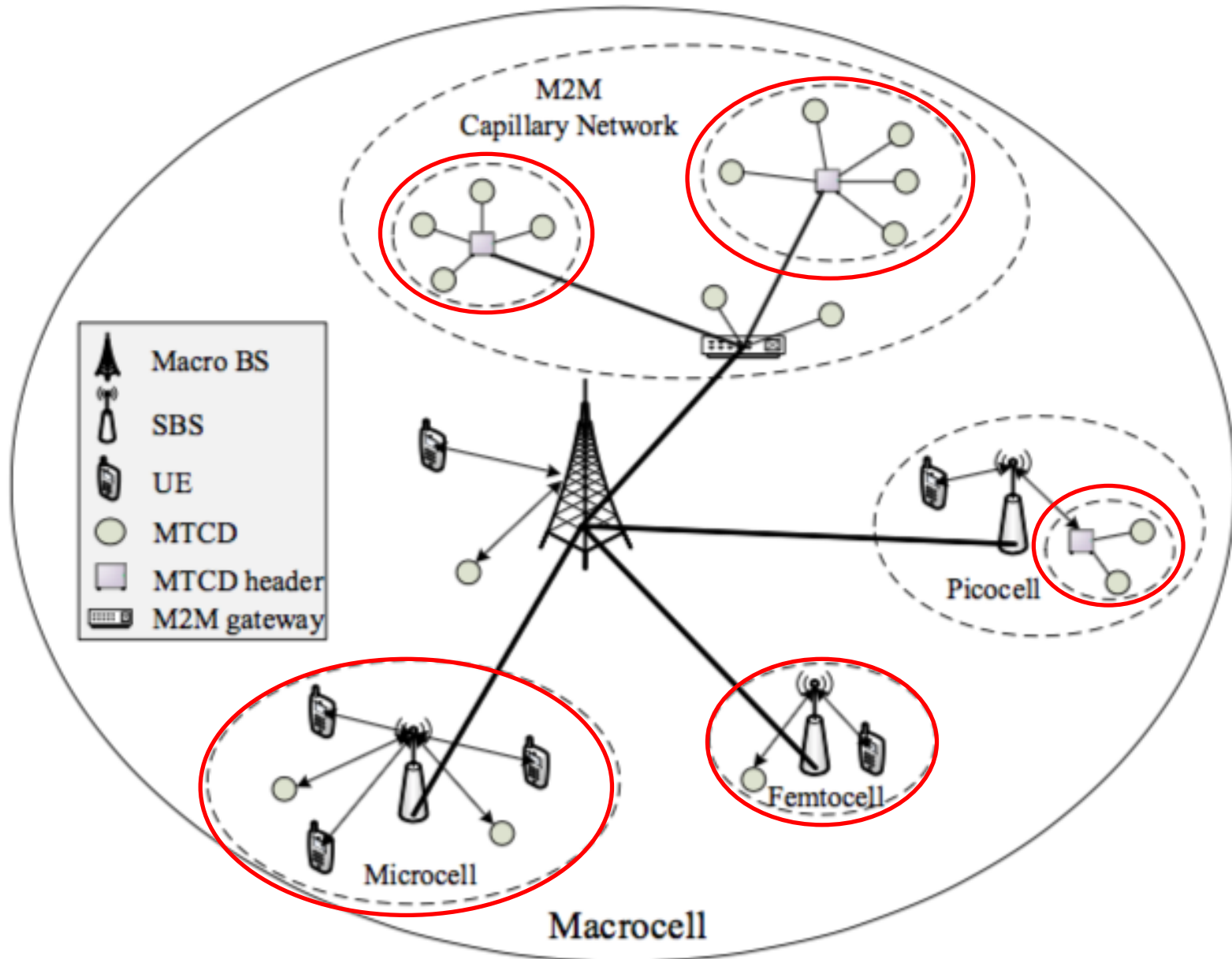
Power control



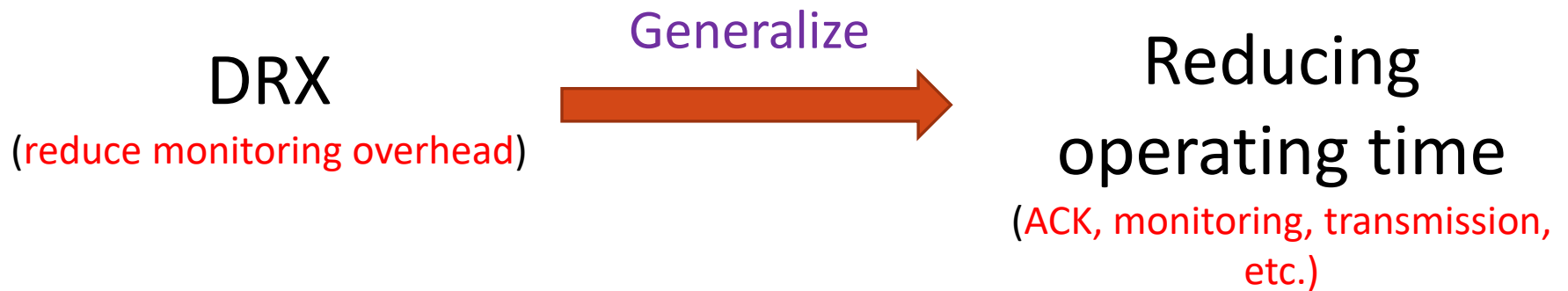
$$SINR = \frac{Signal}{Interference + Noise}$$

Power Class	Nominal maximum output power
1	+33dBm
2	+24dBm
3	+21dBm
4	+27dBm

Clustering methods



Reducing operating time



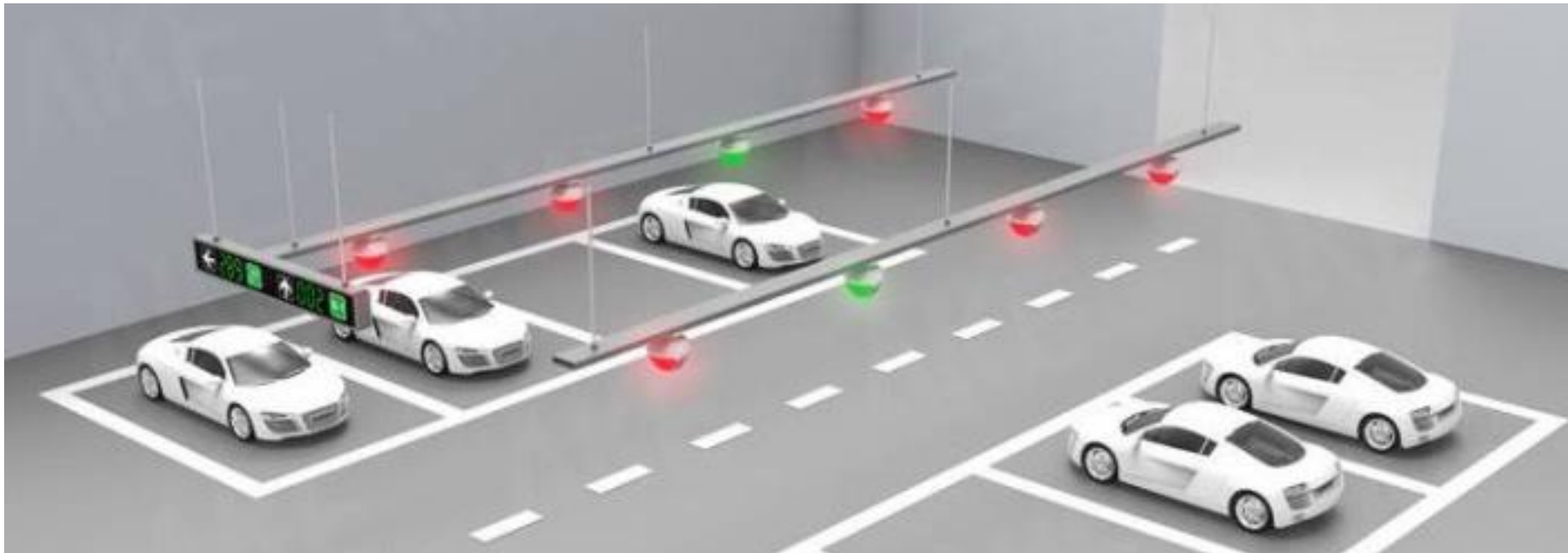
Narrowband IoT (NB-IoT)

Wide coverage

Low energy consumption

Massive connections

Fixed, large number, and low traffic



Narrowband IoT (NB-IoT)

UE Category	Cat-0	Cat-M1	Cat-NB 1
Downlink peak rate	1 Mbps	1 Mbps	~ 200 kbps
Uplink peak rate	1 Mbps	1 Mbps	20 kbps
Transmission power	23 dBm	20 or 23 dBm	20 ~ 23 dBm
Bandwidth	20 MHz	1.08 MHz	0.18 MHz
Duplex mode	Full or half duplex	Full or half duplex	Half duplex



Lowering
complexity

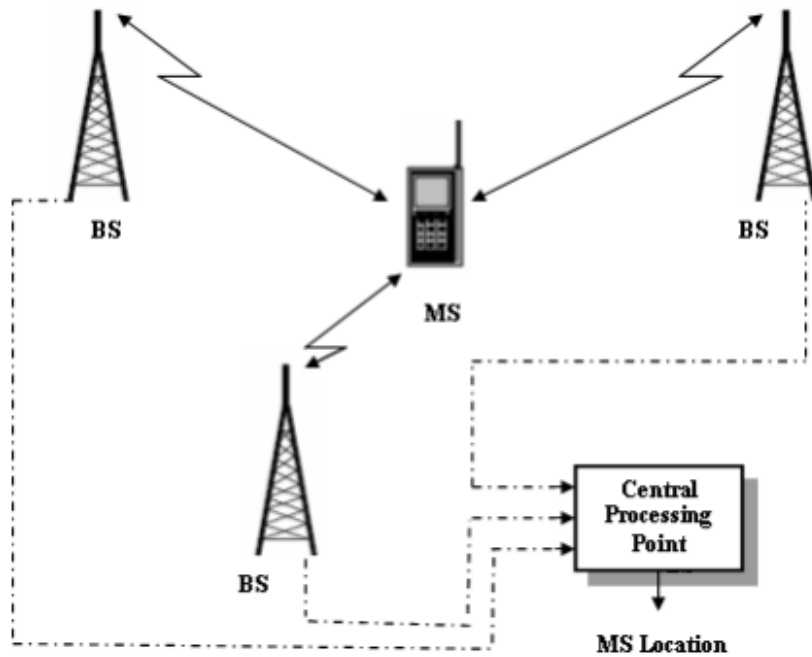
Support new services



Low mobility support



Multicast

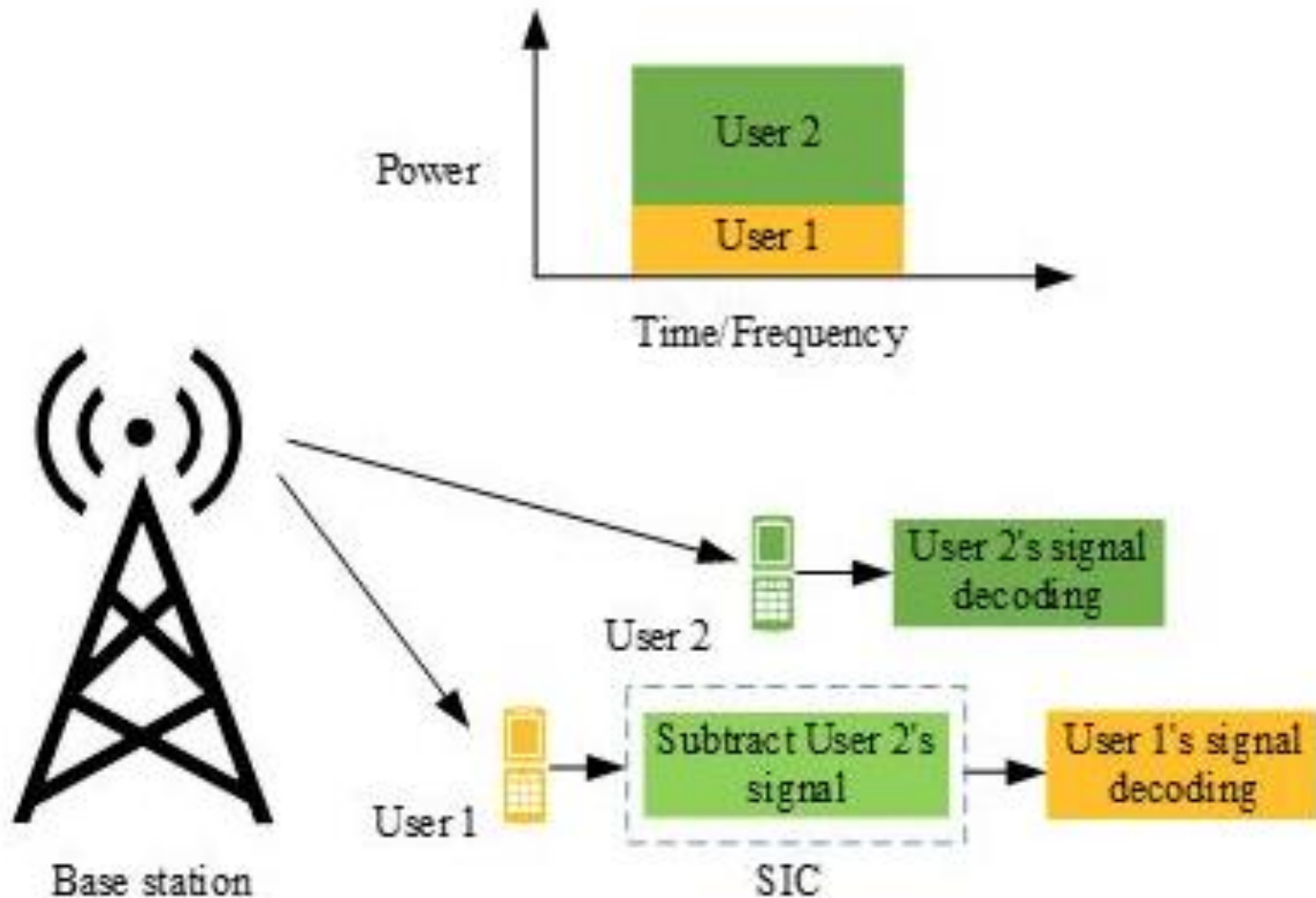


Positioning



New power classes

Non-orthogonal multiple access (NOMA)

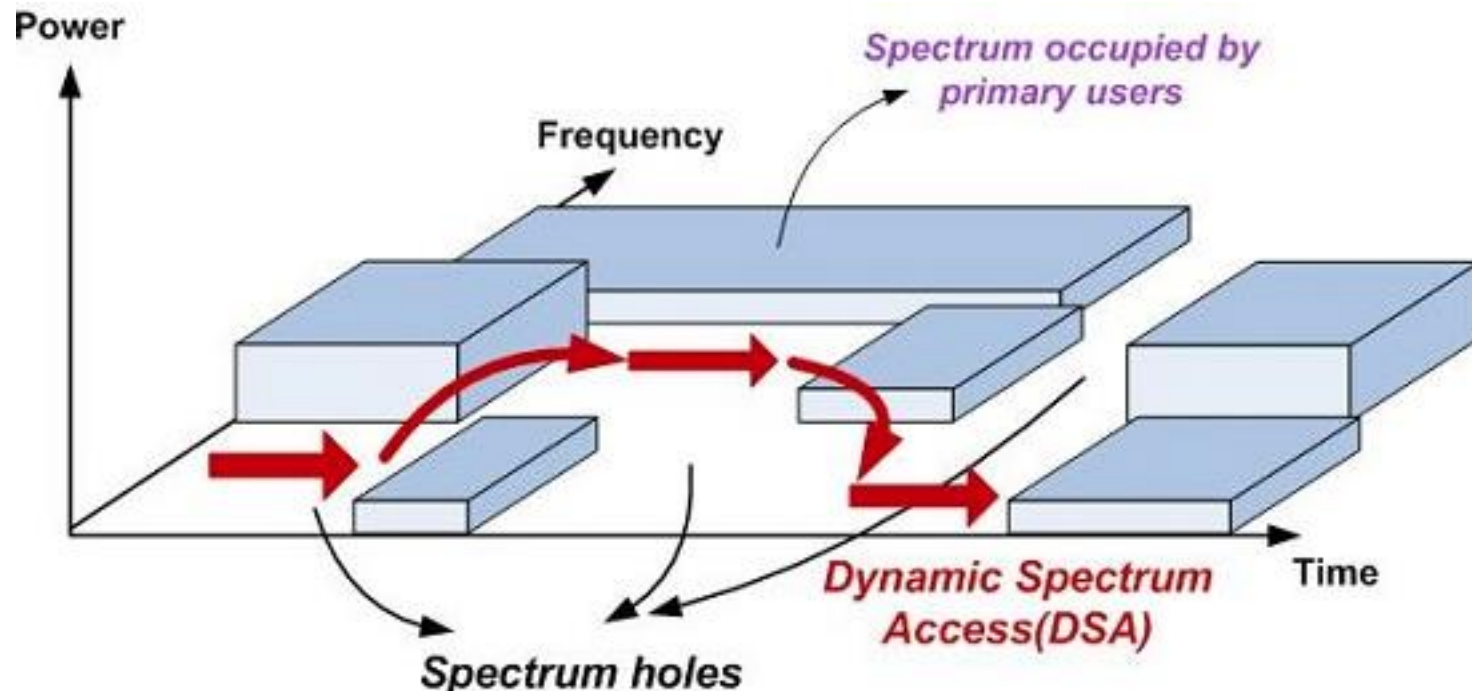


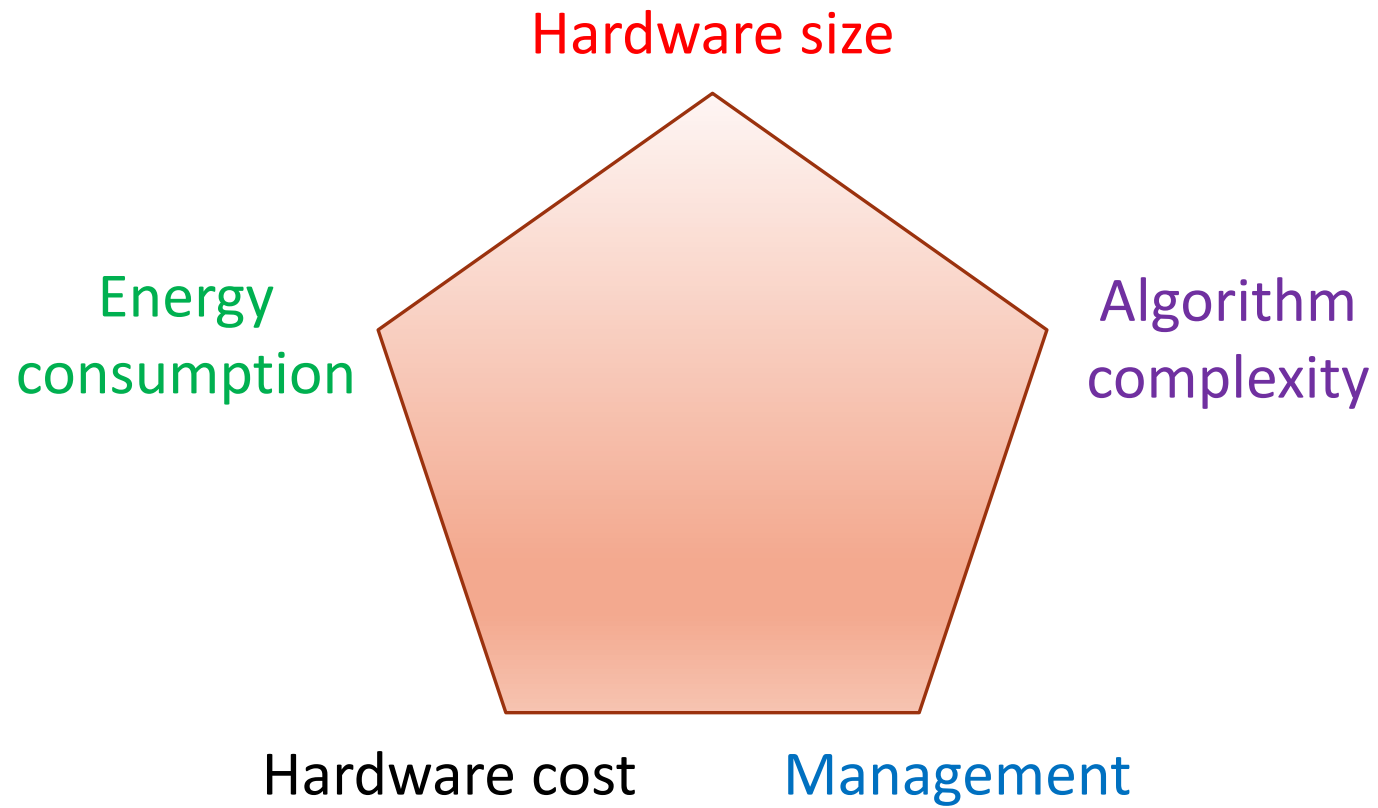
Cognitive M2M

Cognitive Radio + M2M => Spectrum efficiency



Cognitive Radio (CR) allows **unauthorized users** to access **licensed spectrums** **intelligently** on the premise of **not interfering incumbent UEs**.





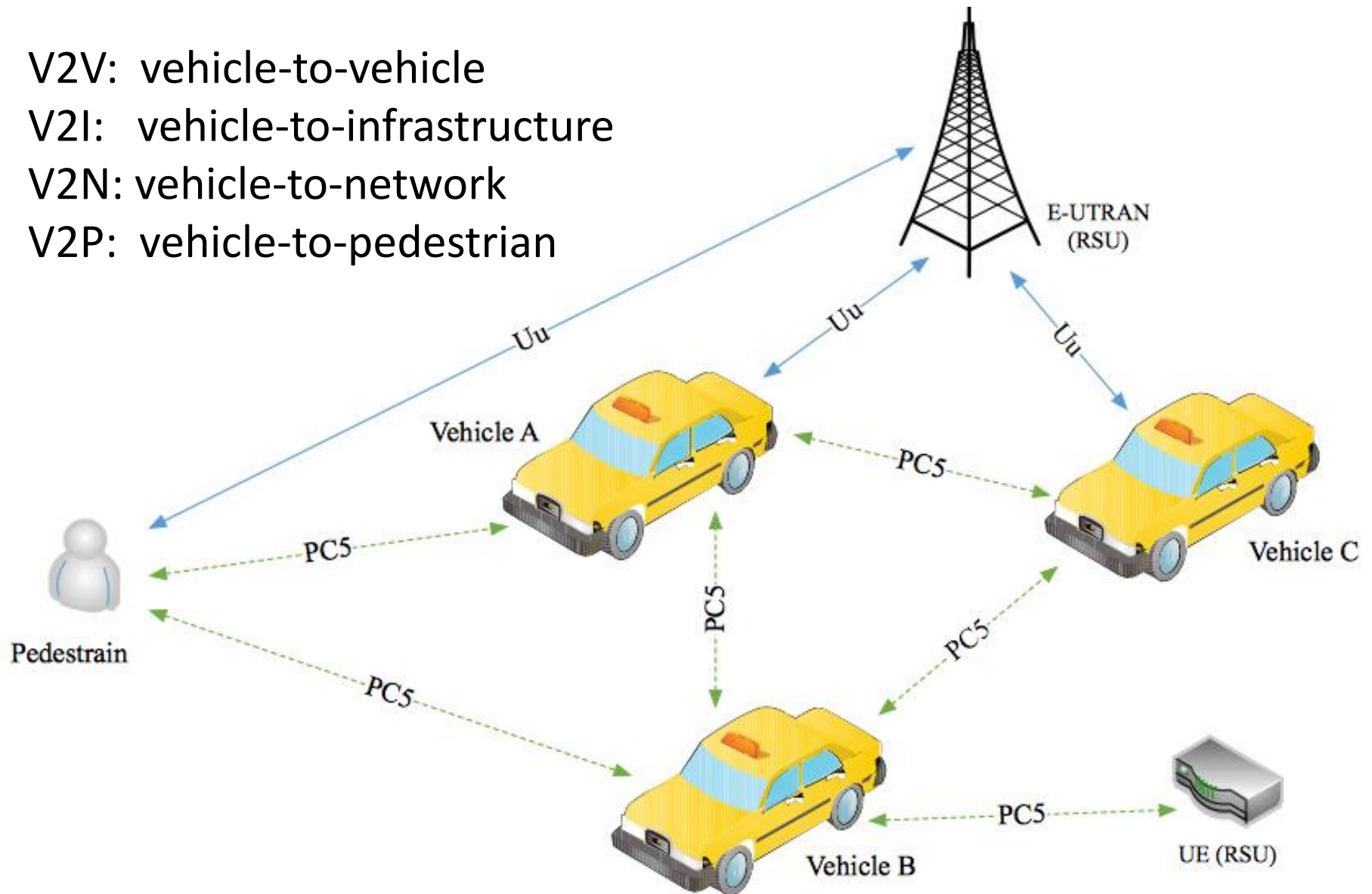
V2X Communications

V2V: vehicle-to-vehicle

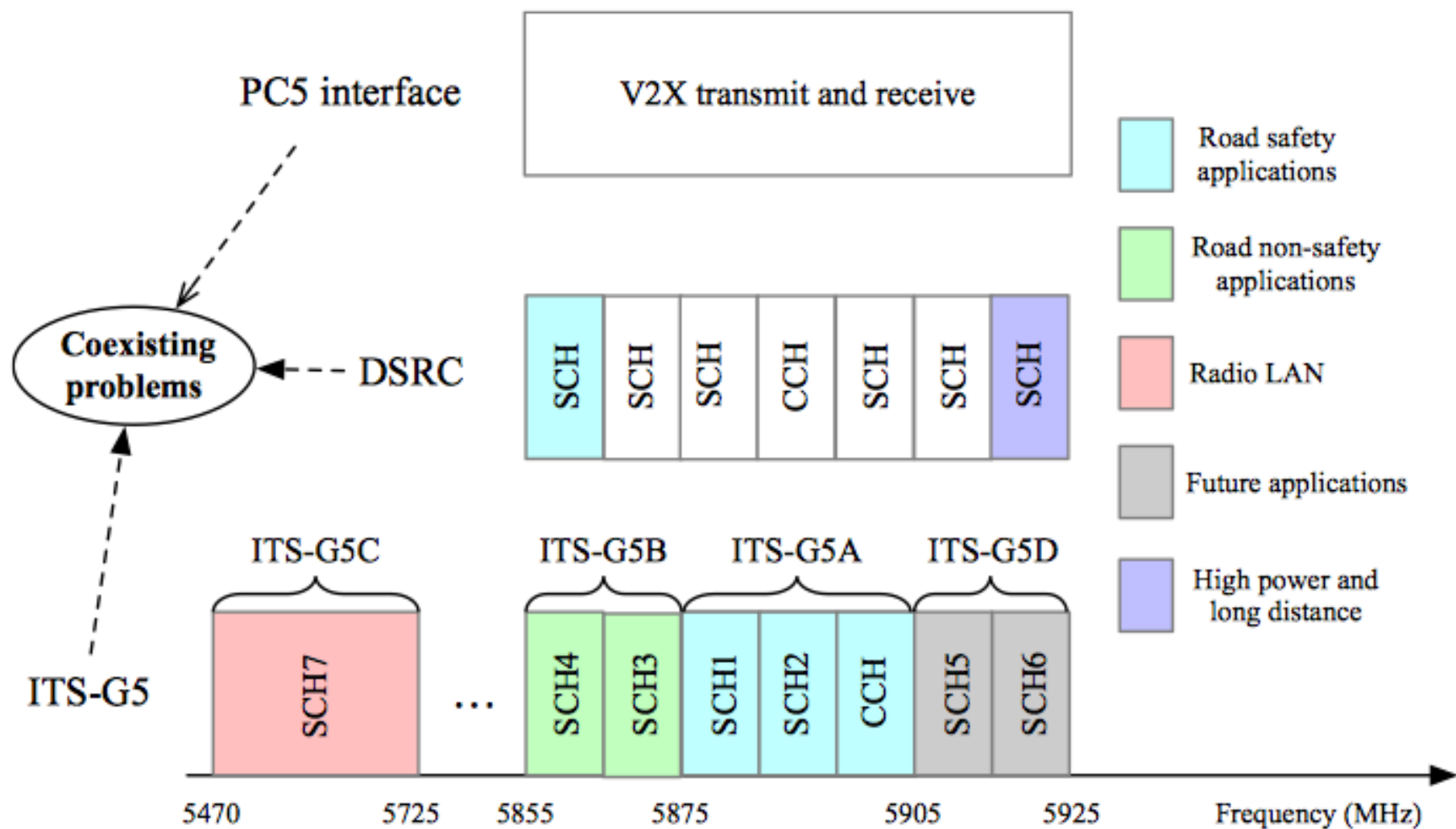
V2I: vehicle-to-infrastructure

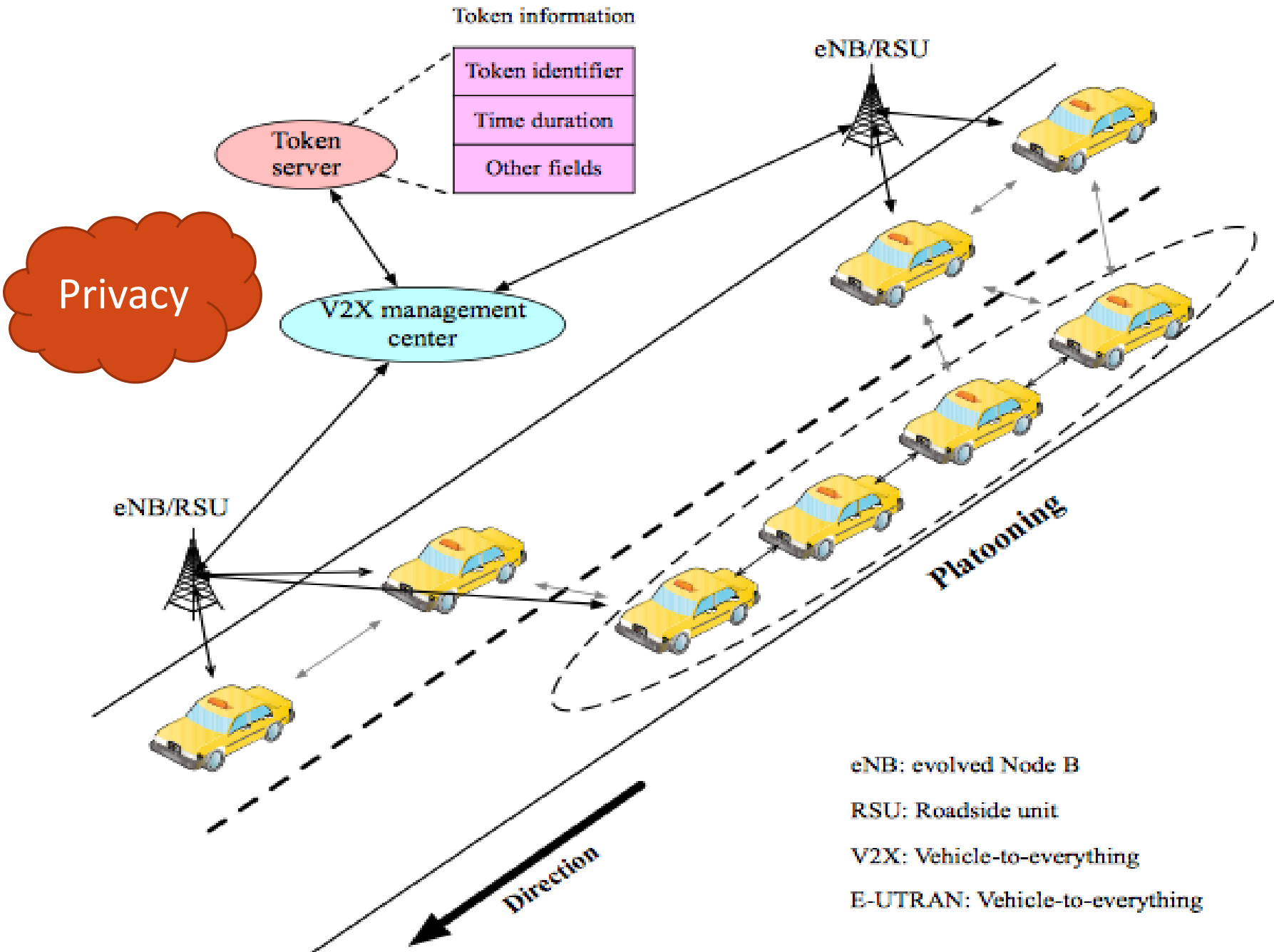
V2N: vehicle-to-network

V2P: vehicle-to-pedestrian

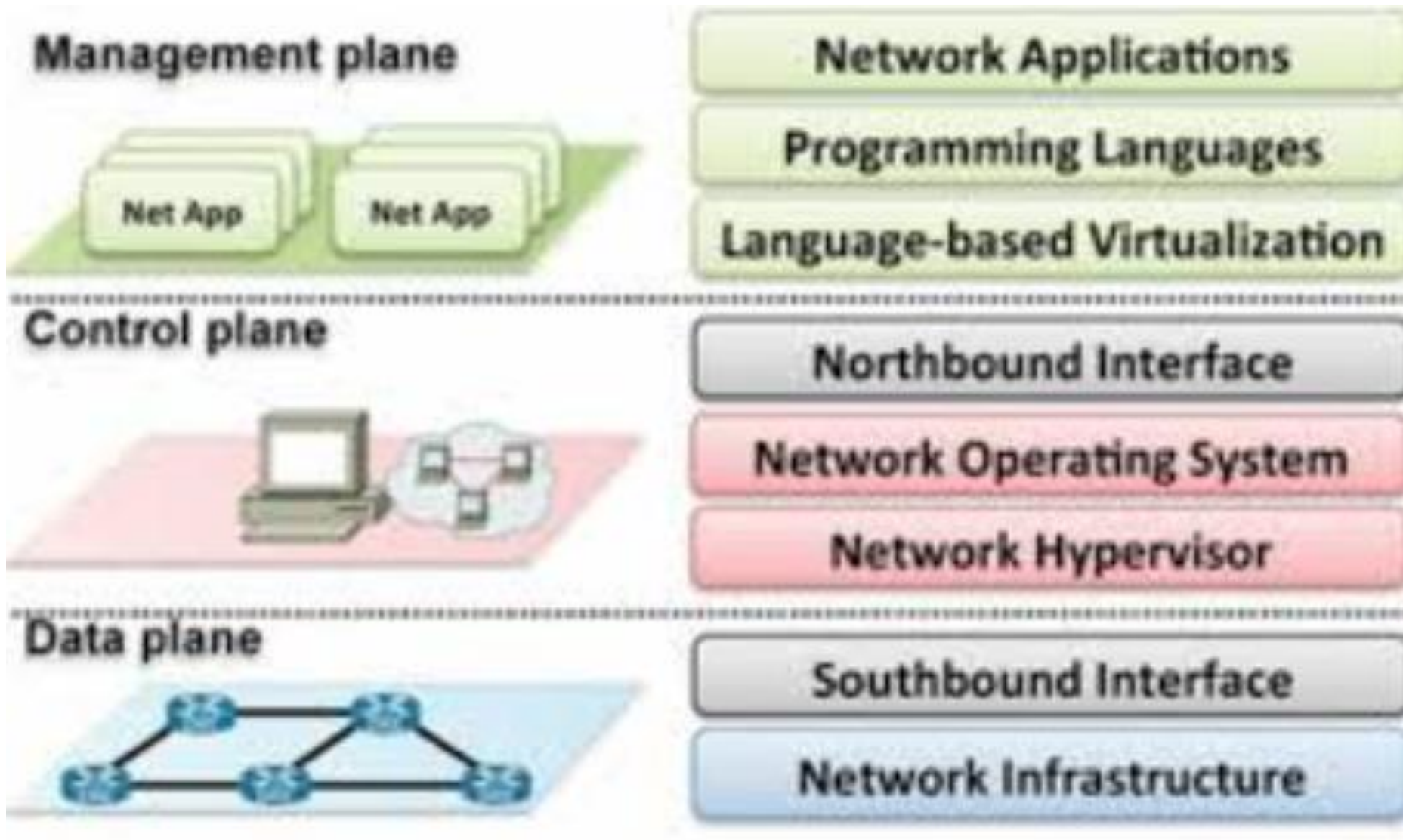


Interface	Operating band	V2X UE transmit (MHz)\ Uplink (UL)	V2X UE receive (MHz)\ Downlink (DL)	Duplex mode
PC5	47	5855 to 5925	5855 to 5925	-
Uu	3	1710 to 1785	1805 to 1880	FDD
	7	2500 to 2570	2620 to 2690	FDD
	8	880 to 915	925 to 960	FDD
	39	1880 to 1920	1880 to 1920	TDD
	41	2496 to 2690	2496 to 2690	TDD

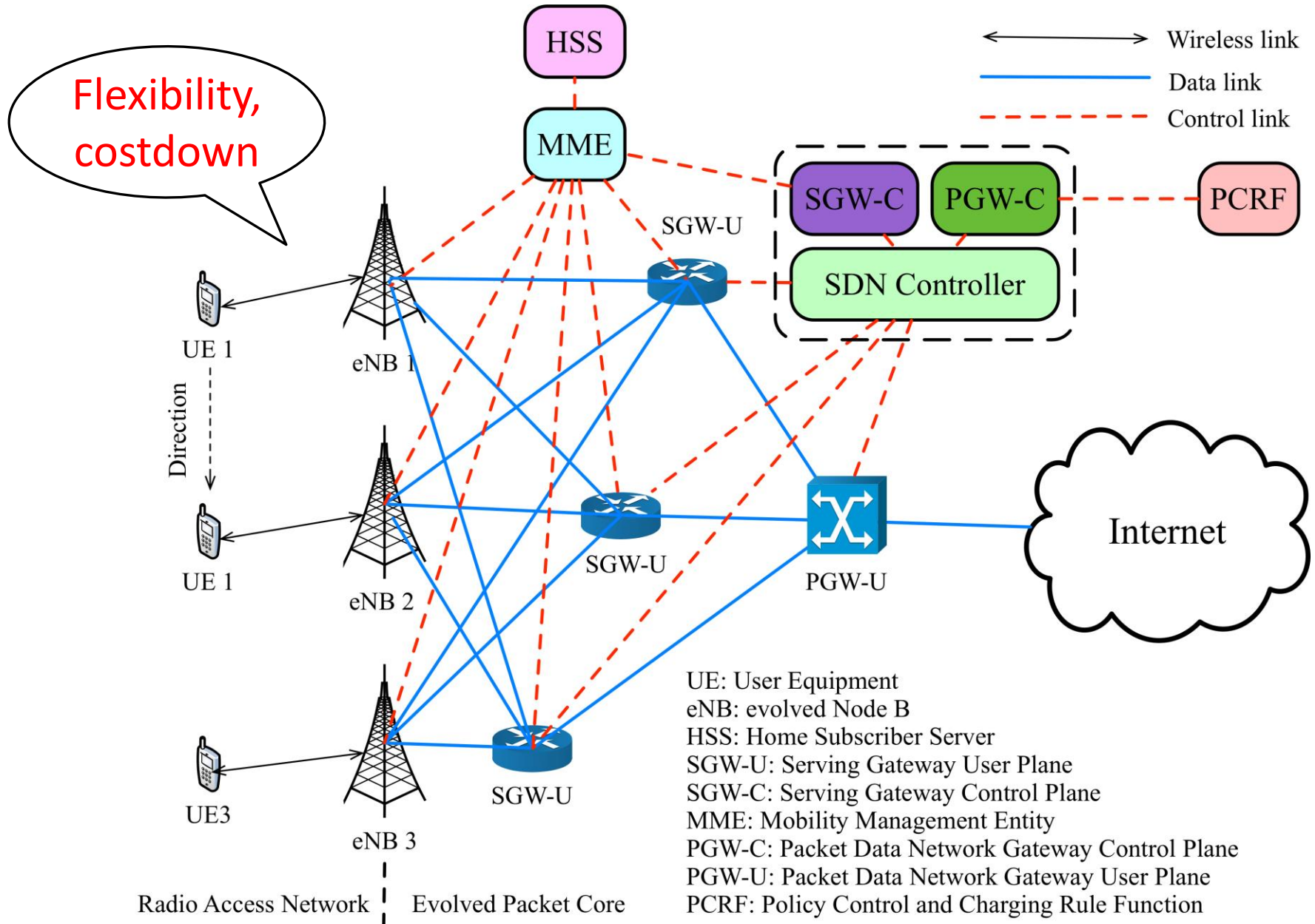


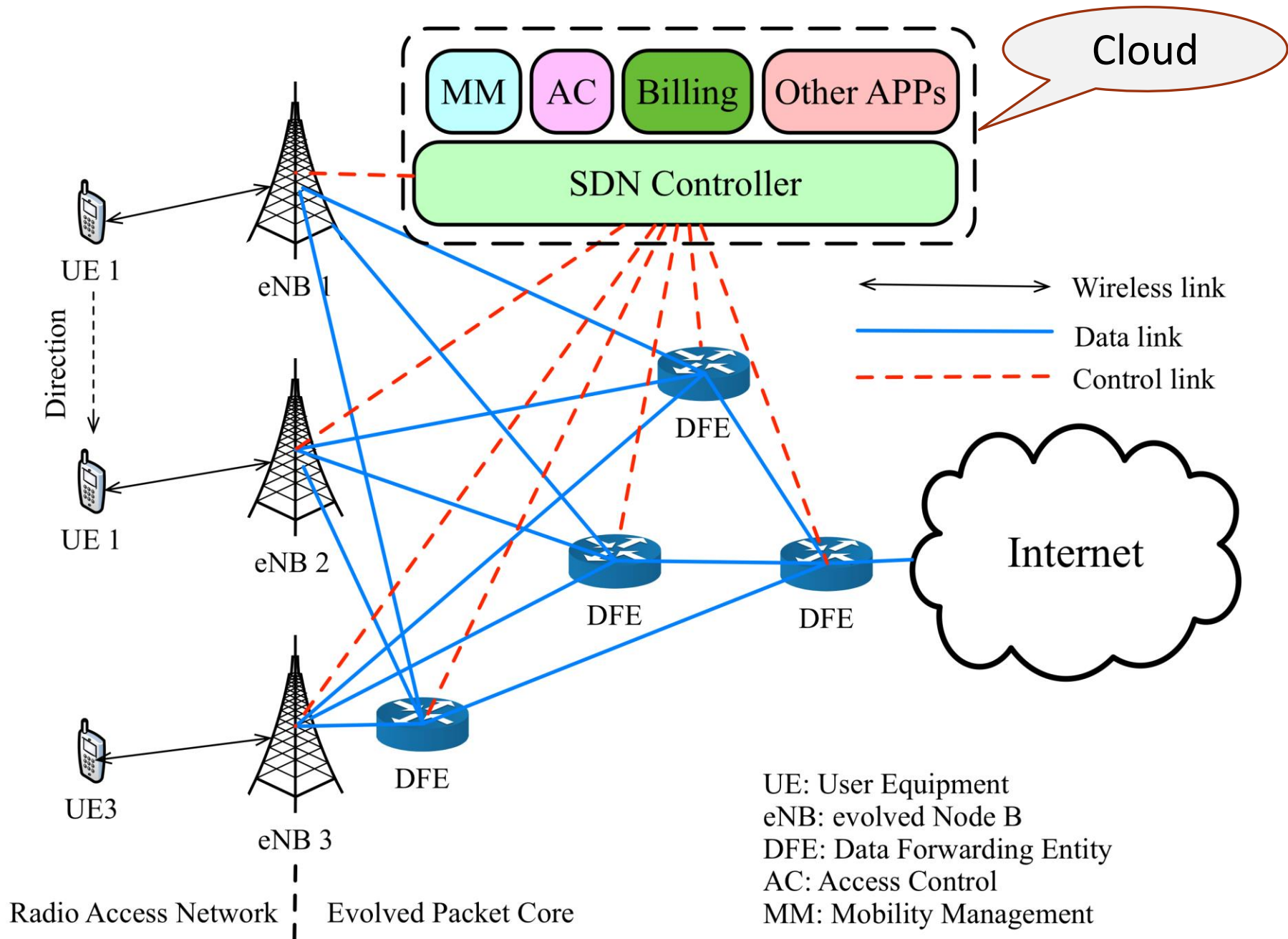


Software defined networking (SDN)

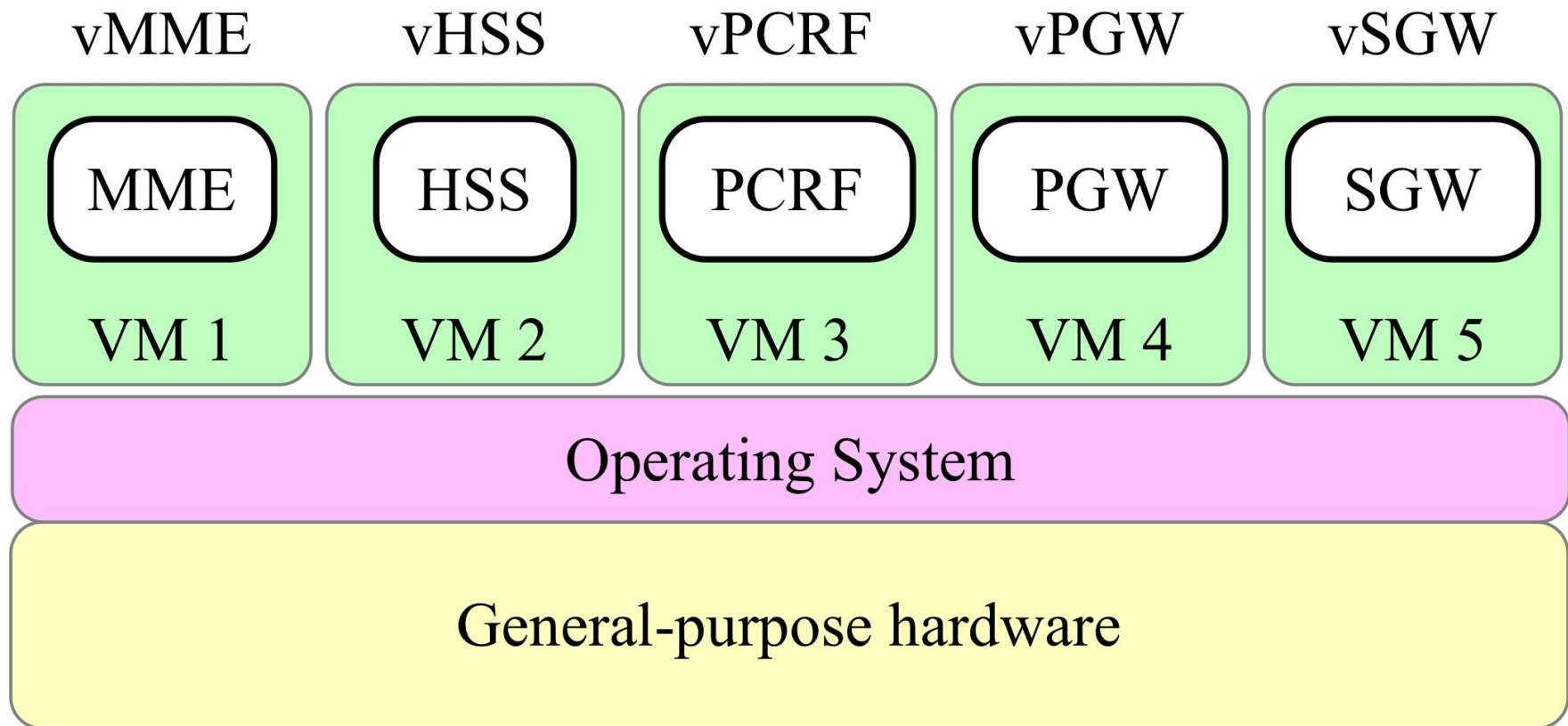


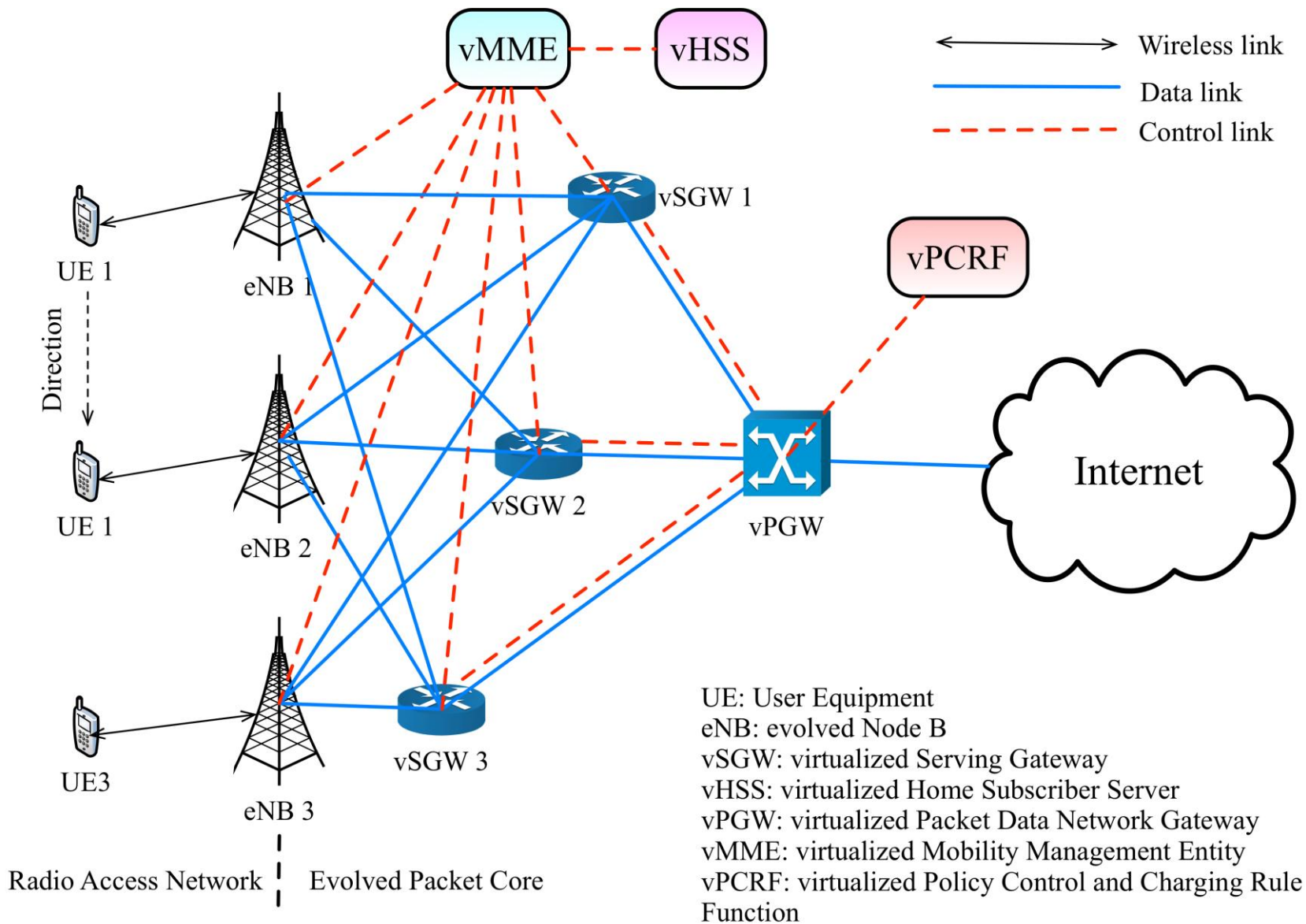
SDN-based M2M





Network Function Virtualization





Thank you for your attention!