what is in for D2D in 5G wireless

support of underlay low-rate M2M links

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5G

will not only be

“4G, but faster”

5G research @ EU

FP7 METIS
Mobile and wireless communications
Enablers for the Twenty- twenty (2020)
Information Society

Budget: 27 M€.

Objective: 5G by 2020

system concept that meets the requirements of the 2020 connected information society and extend today's wireless communication systems to support new usage scenarios. Such a system has to be more **efficient, versatile**, and **scalable** compared to today's systems.

METIS system concept

immense task, split into 5 Horizontal Topics

- direct Device-to-Device communication (D2D)

how to efficiently enable and for what to use D2D

- Massive Machine Communication (MMC)

how to support a massive number of low-cost, low-energy devices

METIS system concept

- Moving Networks (MN)

extend the current wireless infrastructure to moving/nomadic nodes and create new services

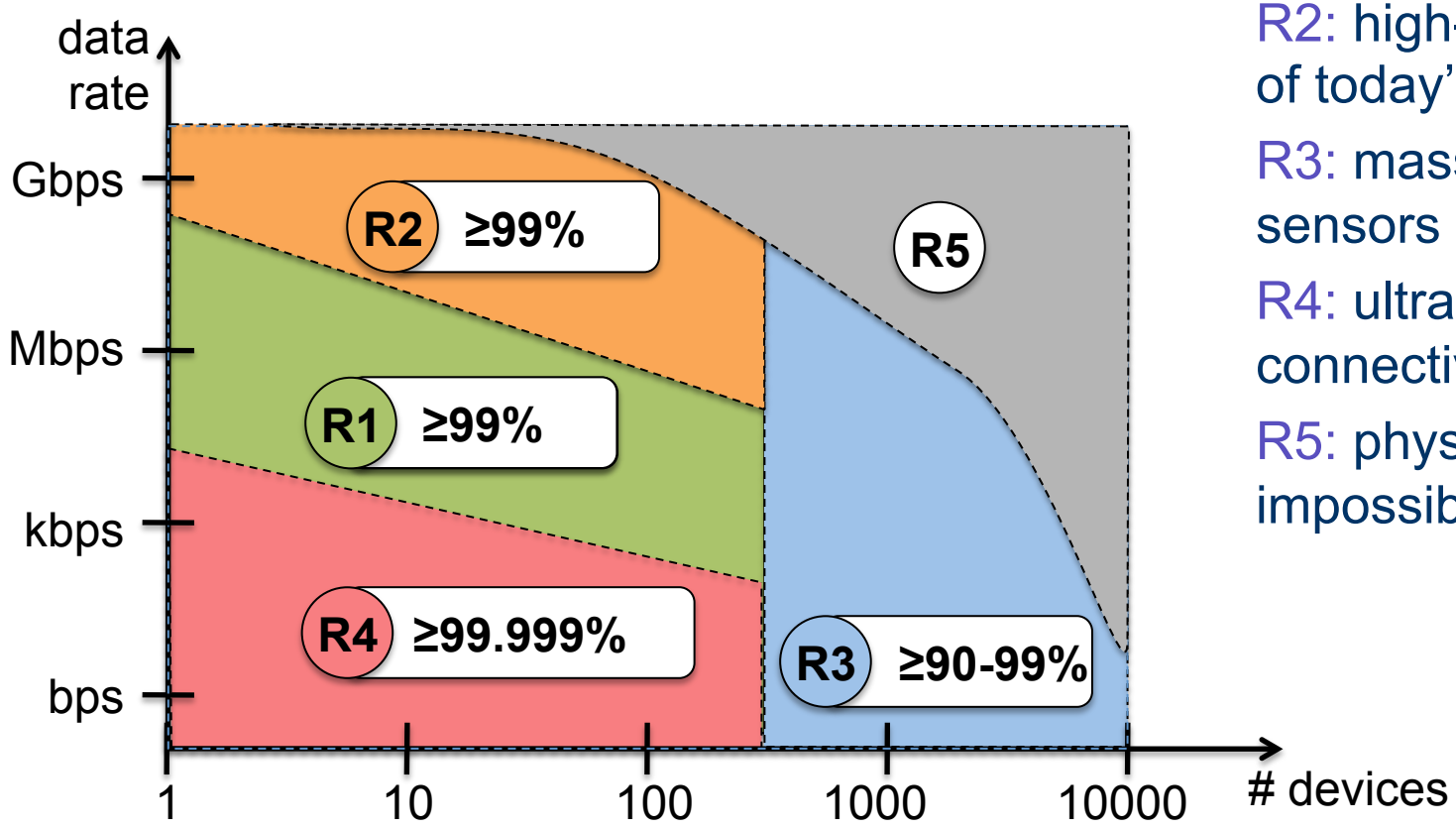
- Ultra-Dense Networks (UDN)

provide and sustain high rates to a large number of users in close proximity

- Ultra-Reliable Communication (URC)

how to guarantee certain connectivity or latency 99.999+% of the time

a biased personal summary of 5G



R1: today's systems

R2: high-speed versions of today's systems

R3: massive access for sensors and machines

R4: ultra-reliable connectivity

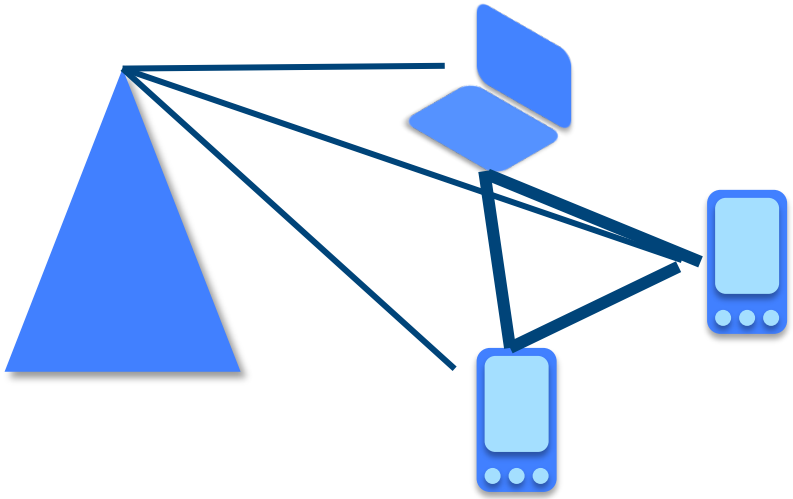
R5: physically impossible

direct D2D

refers to local D2D communication controlled by the core network

it can potentially improve

- reliability
- latency
- throughput per area
- spectral efficiency
- machine-type access

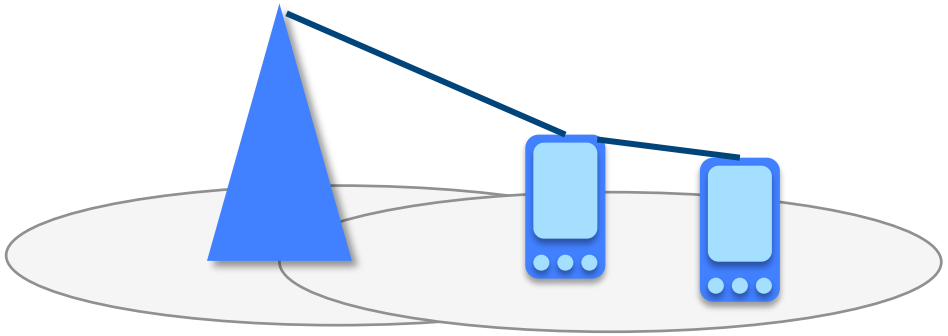


new services

D2D for reliability

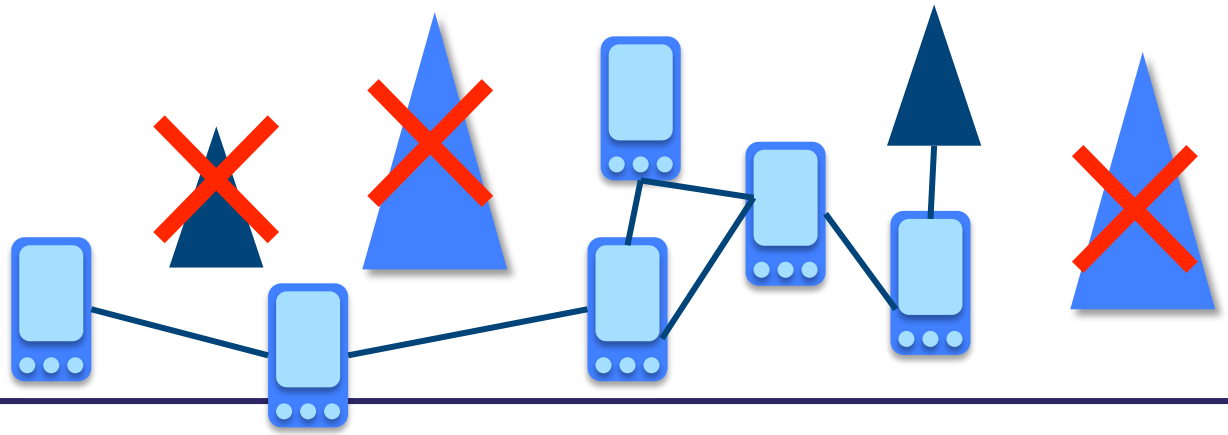
extended coverage

- multi-hopping
- network coding
- cooperative diversity



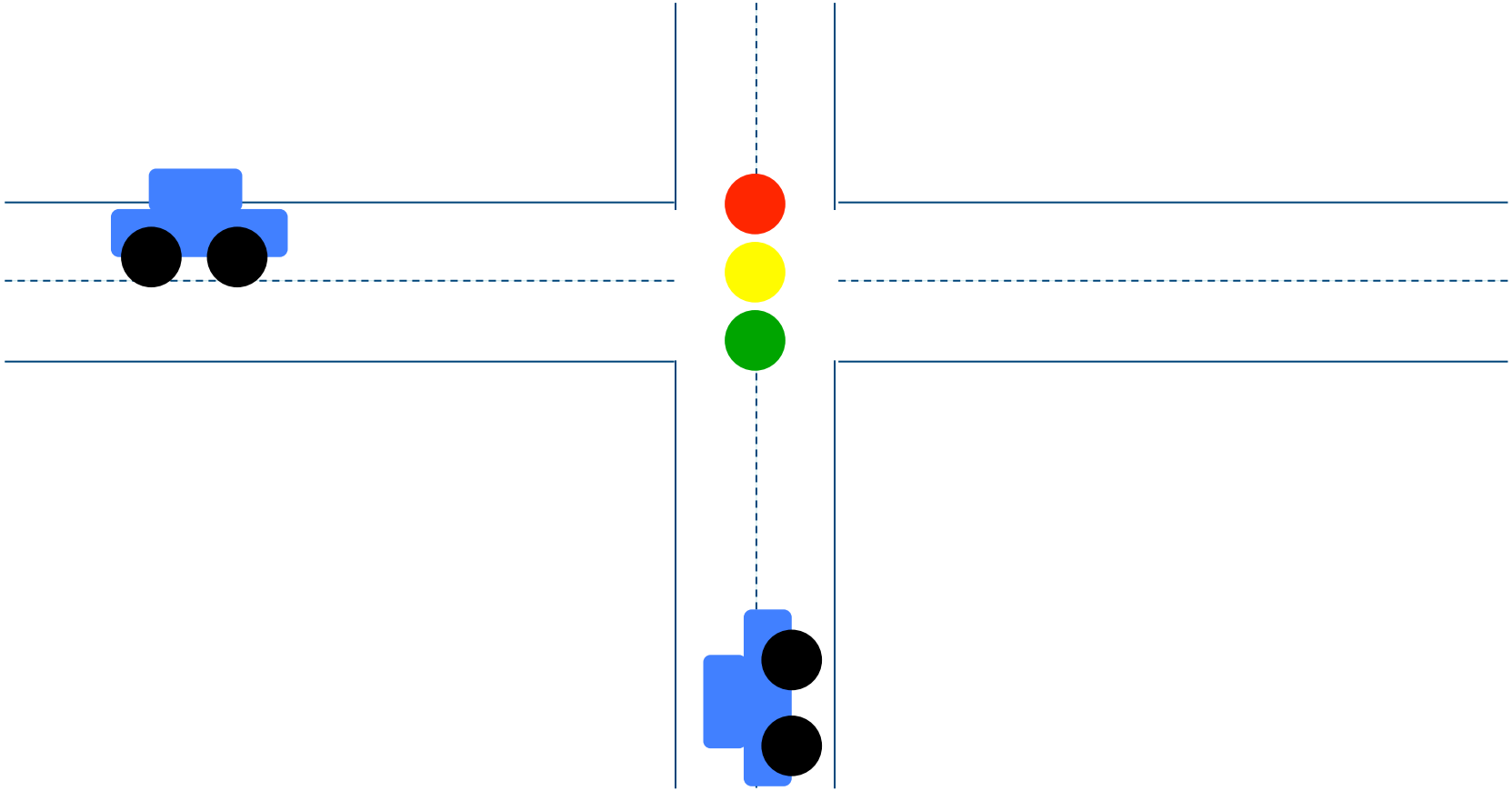
ad hoc networking in emergency

fallback solution



D2D for latency

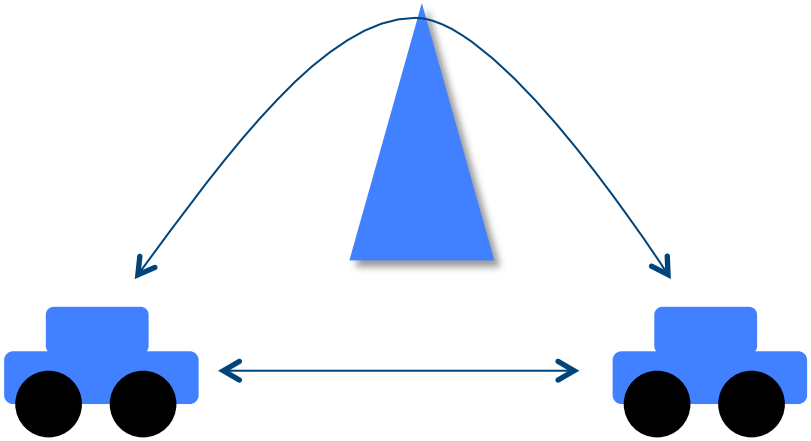
- how to do this reliably in 2020+?



D2D for latency

network-controlled D2D has an advantage over pure Bluetooth-like D2D

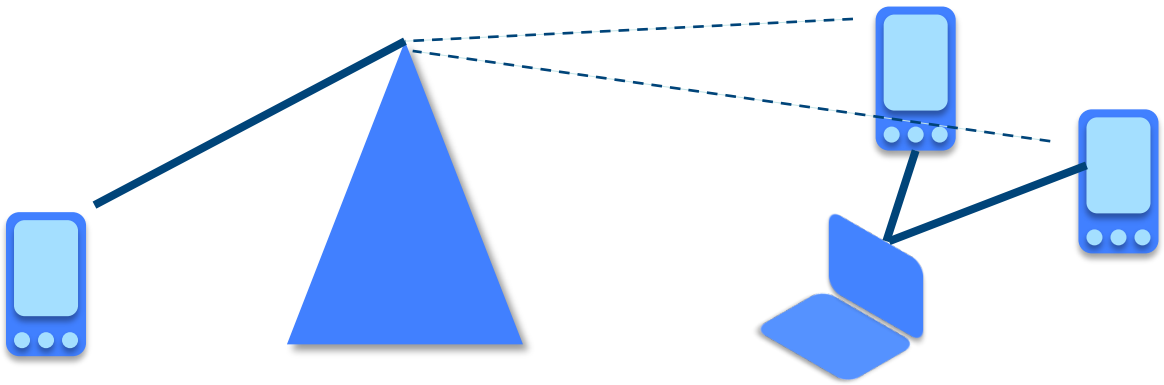
- facilitates **leader election** in neighbor **discovery** and link **rendezvous**
- interference control (licensed spectrum)
- diversified connection



D2D for throughput

offloading and local content sharing

close connection to caching

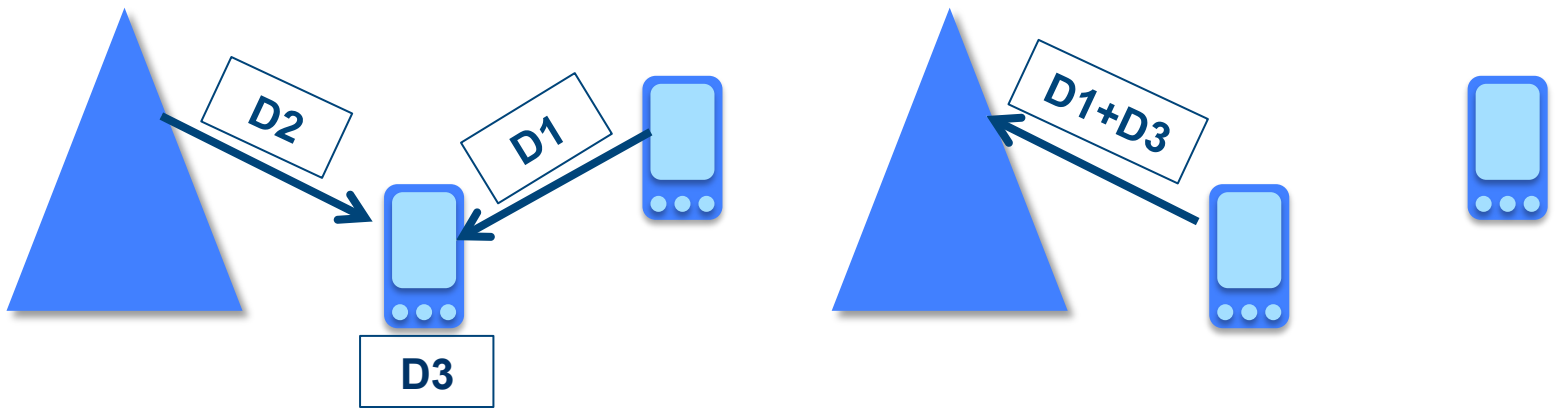


D2D for spectral efficiency

the D2D setting looks like a

cognitive radio with consensual primary

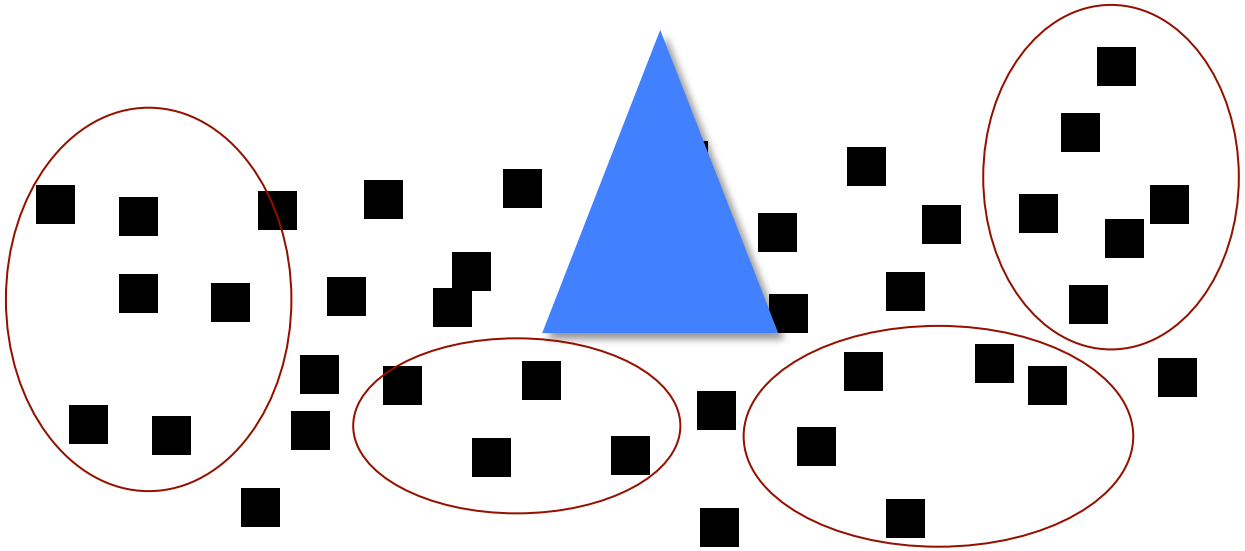
- spectral efficiency in the previous example
- another example is to use the features of the multiple access channel



D2D support of machine-type access

trunking effect and coordination

decrease the random access pressure on the Base Station

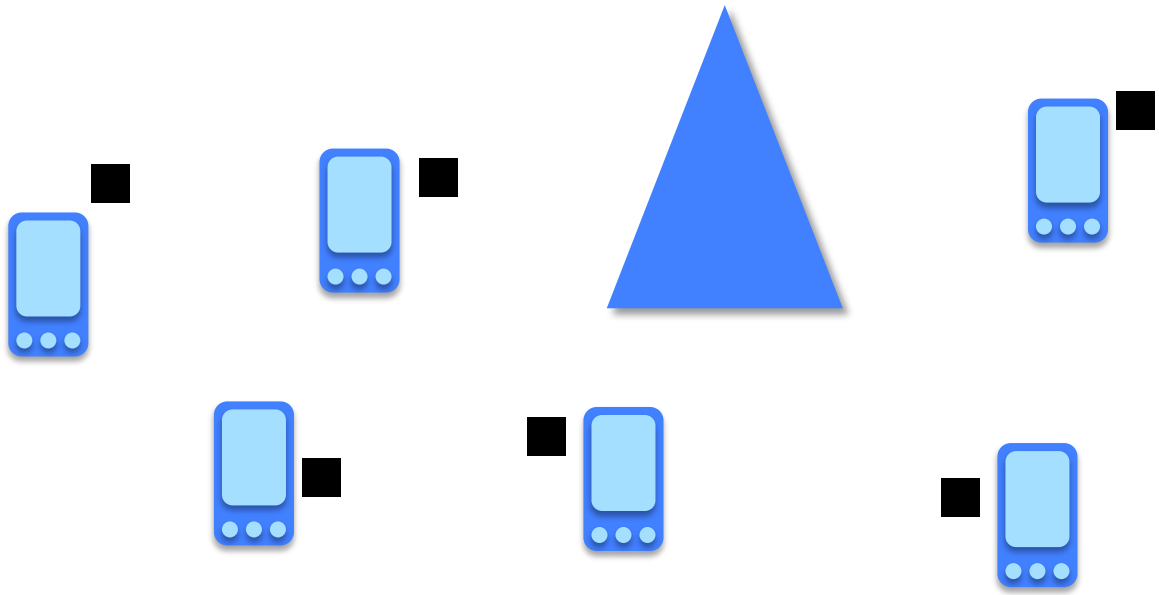


D2D support of machine-type access

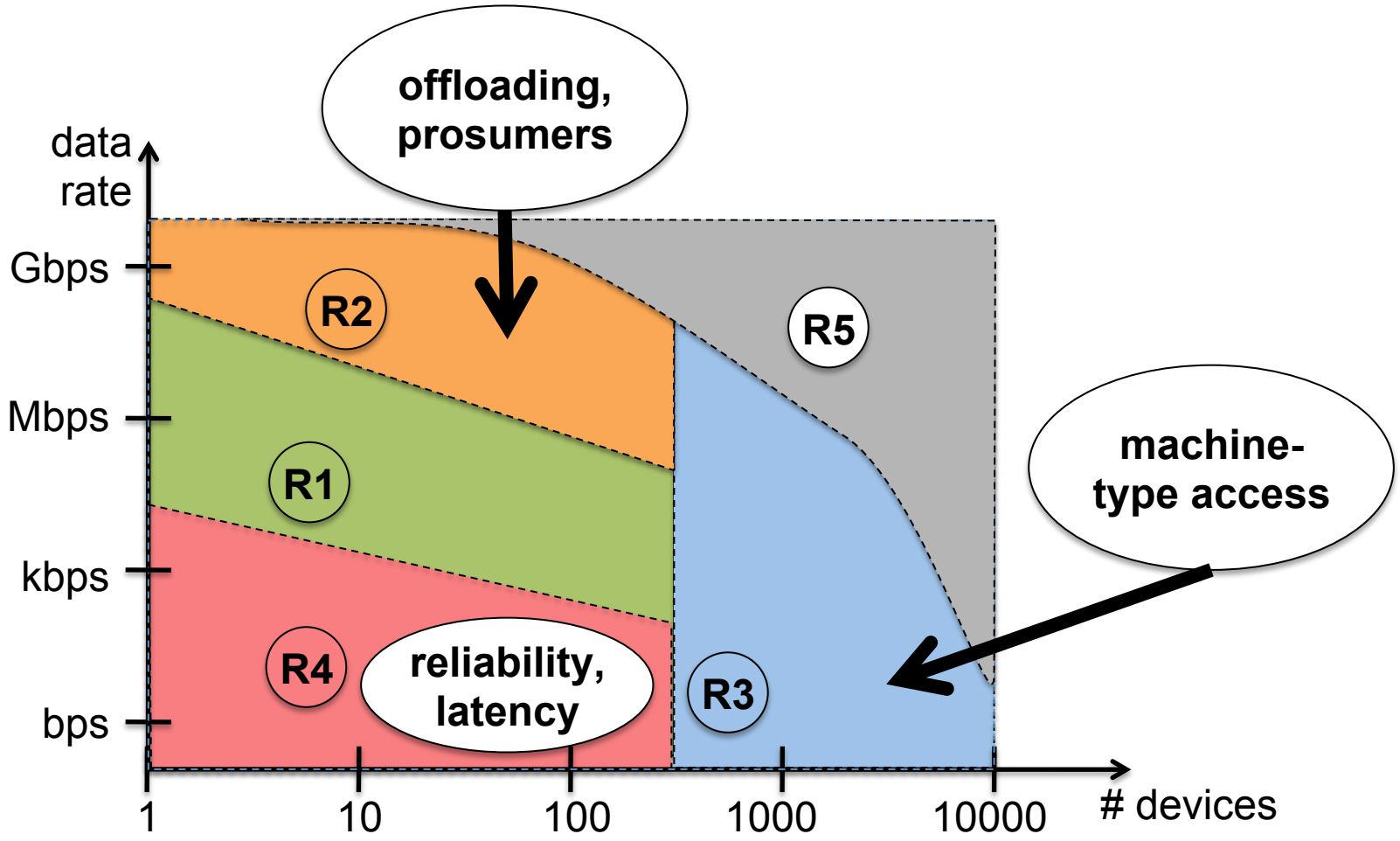
low power uplink

sensor attached to a phone

underlay operation in the same spectrum

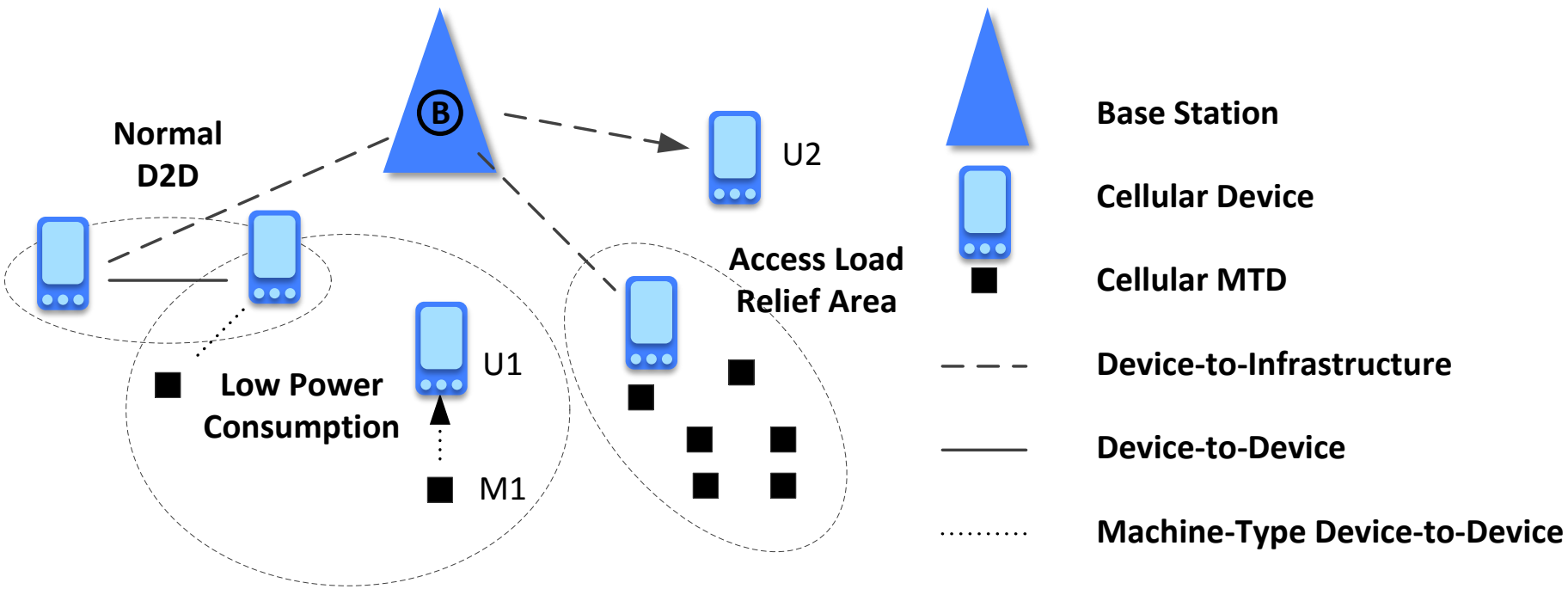


D2D in the 5G diagram

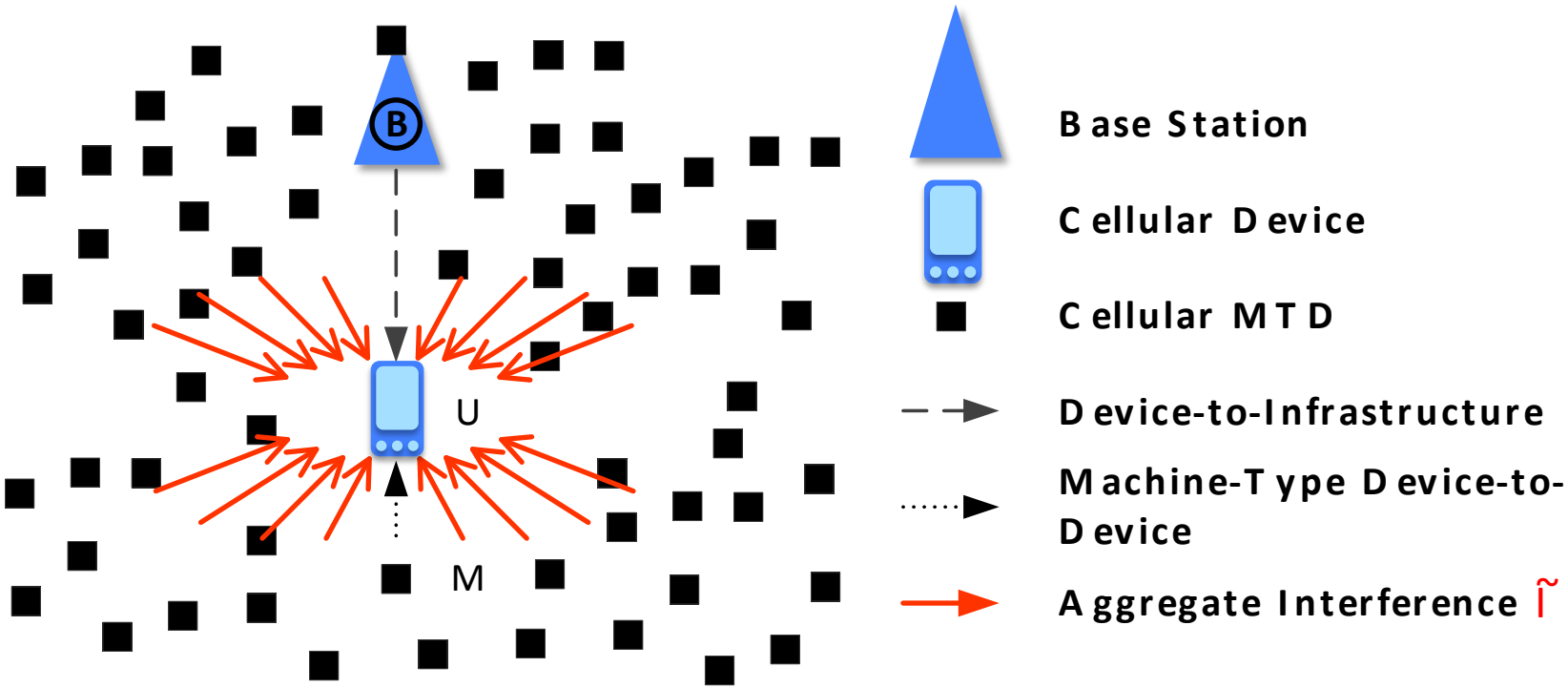


D2D for underlay machine-type access

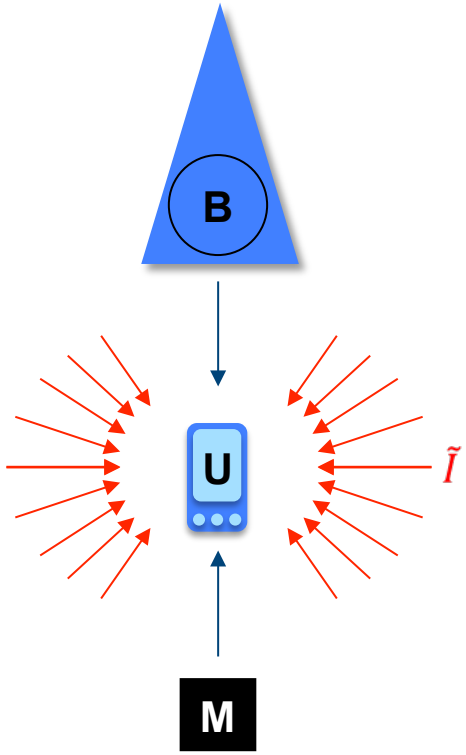
scenario of machine-type D2D



model of underlay operation



problem definition



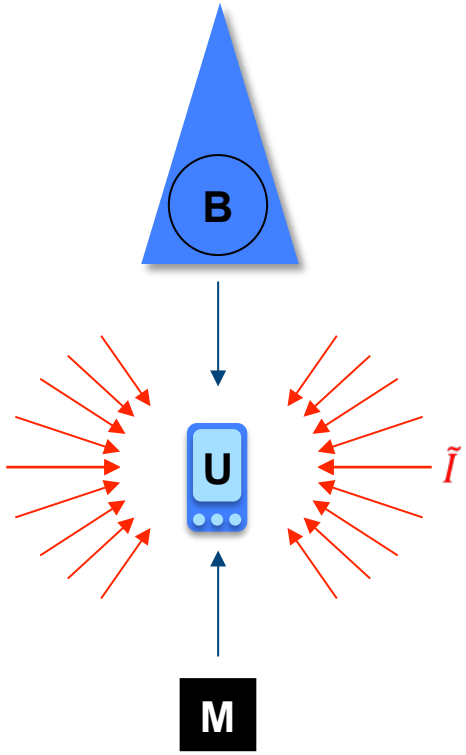
assume that B knows the channel B-U

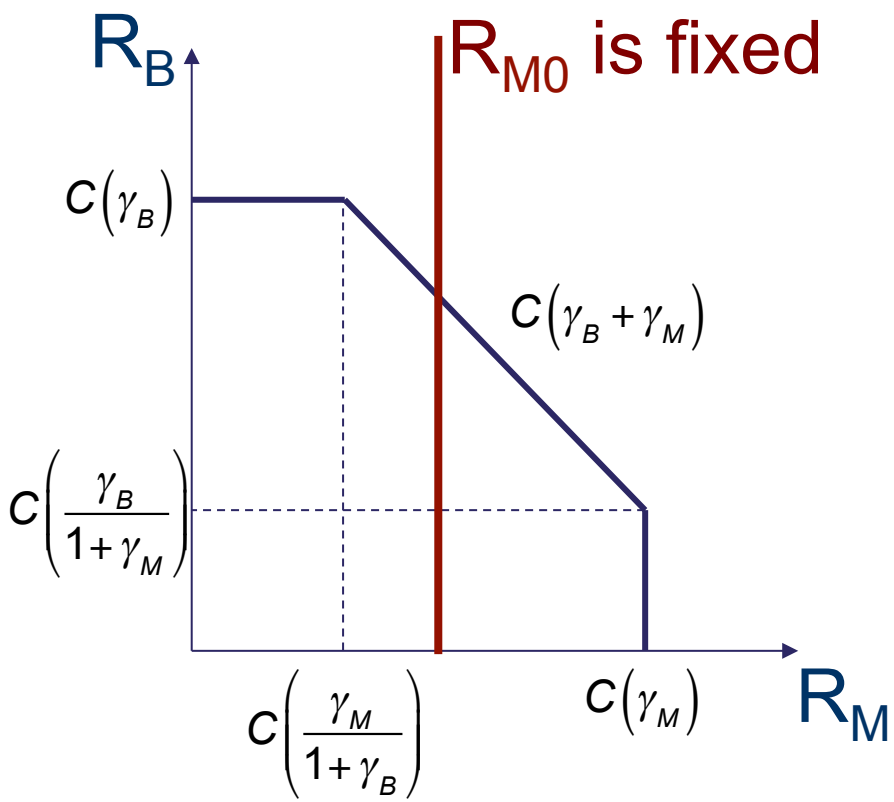
but not the channel M-U

U can decode both
signals from B and M

how should B select the downlink rate R_B,
so that the downlink transmission
is not in outage?

multiple access channel at U

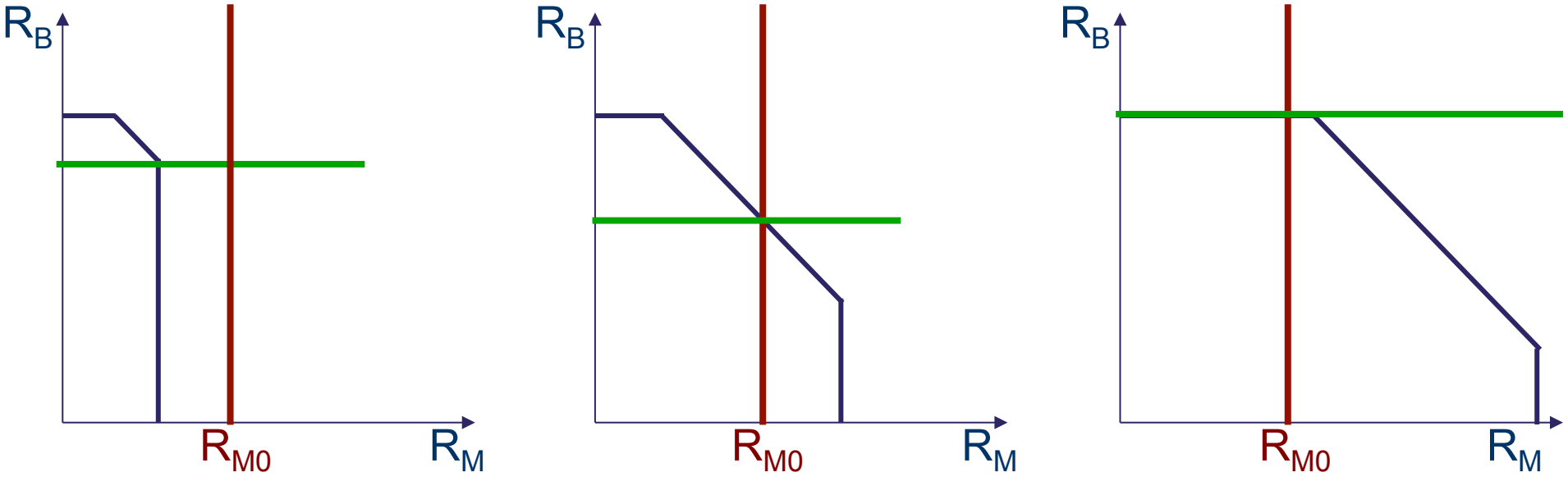




low R_{M0} candidate for interference cancelation

three MAC regimes with joint decoding (JD)

maximal decodable R_B



R_{M0}
not decodable

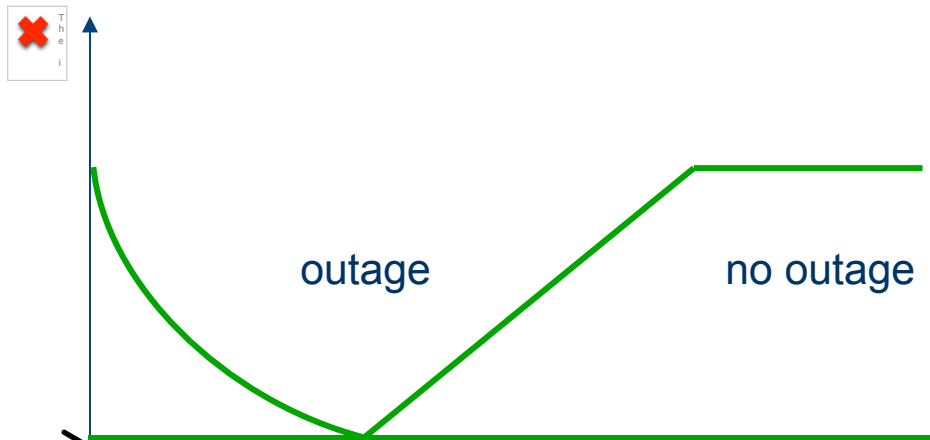
joint decoding
of R_B and R_{M0}

SIC:
R_{M0} removed
first

max R_B as a function of the strength of the link M-U

rates R_B and R_{M0} represented equivalently through SNRs Γ_B and Γ_M

$$\Gamma_B = \frac{\gamma_B}{1+\Gamma_M}$$



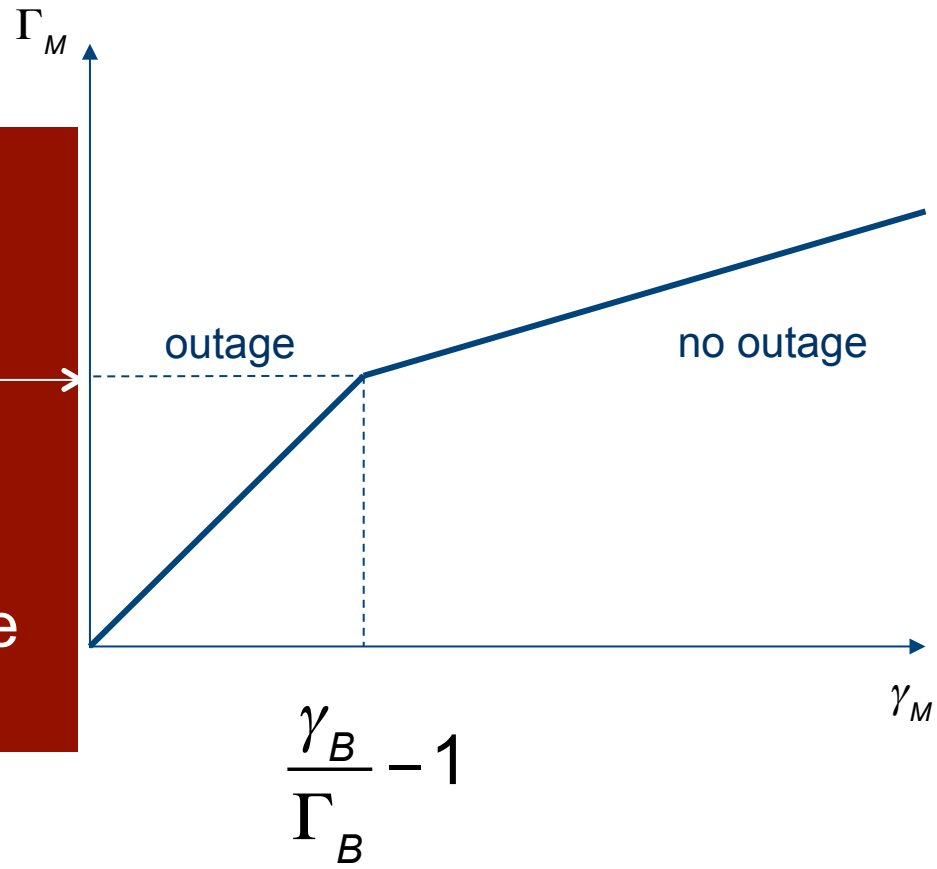
possible to select R_B and avoid outage independently of the fading statistics for M-U

outage for the link M-U

below this value

$$\frac{\gamma_B}{\Gamma_M} - 1$$

outage affected only by the statistics of the M-U link



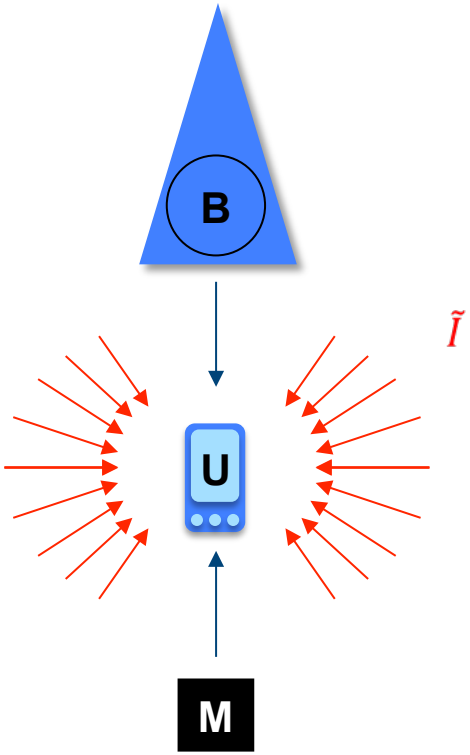
maximal zero-outage rate

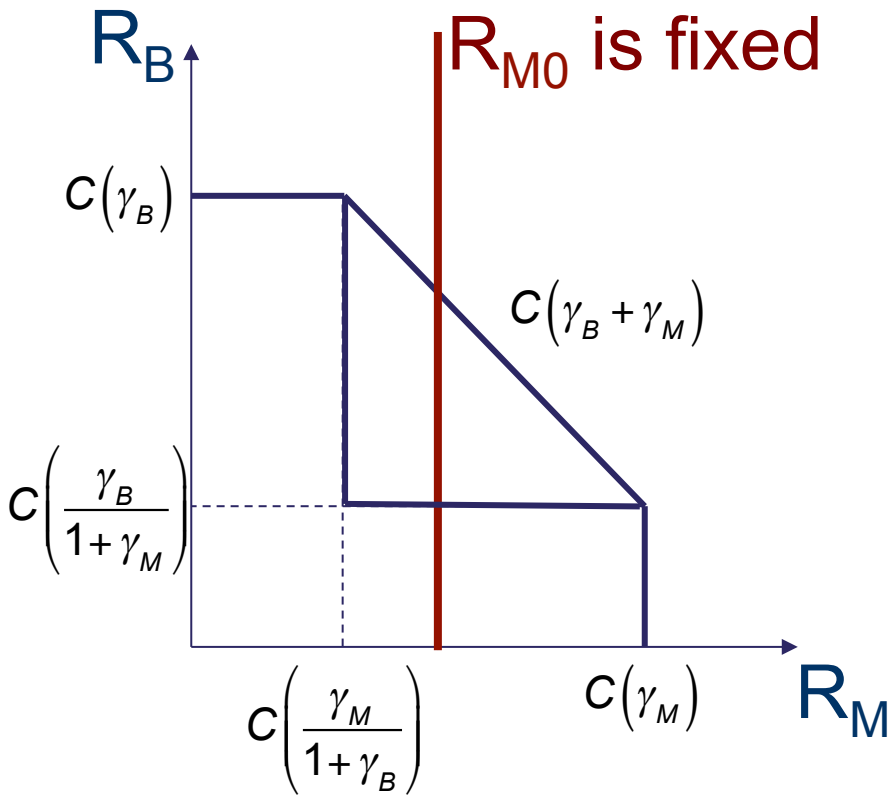
$$R_B = \log_2\left(1 + \frac{\gamma_B}{1+\Gamma_M}\right) = C\left(\frac{\gamma_B}{1+\Gamma_M}\right)$$

increases as the rate

R_{M0} (Γ_M) decreases

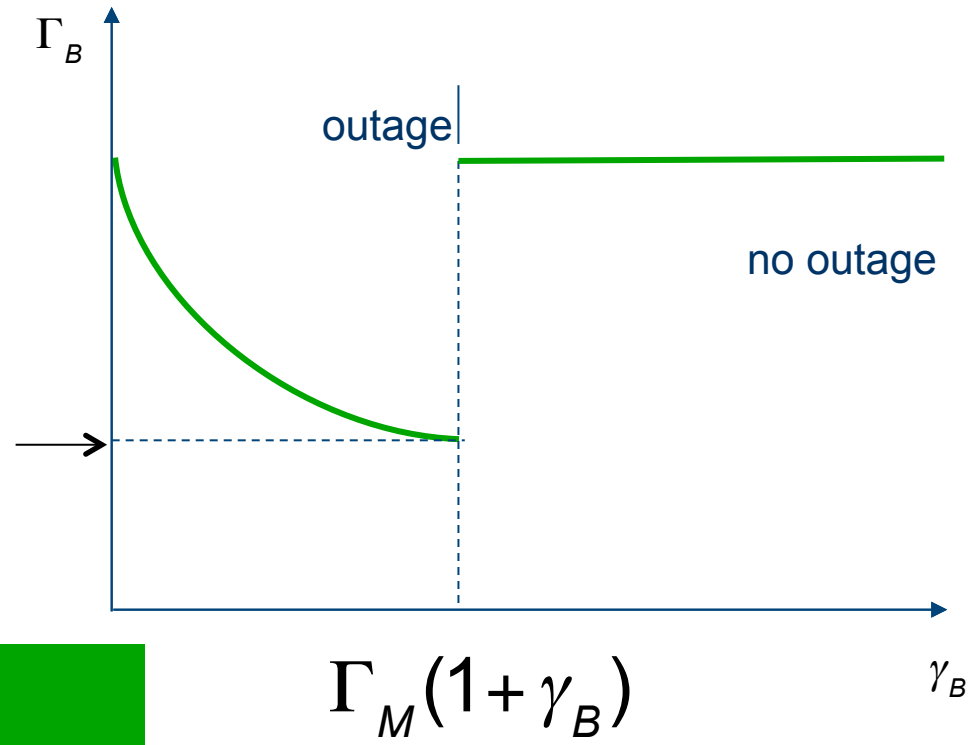
a simple single-user decoder





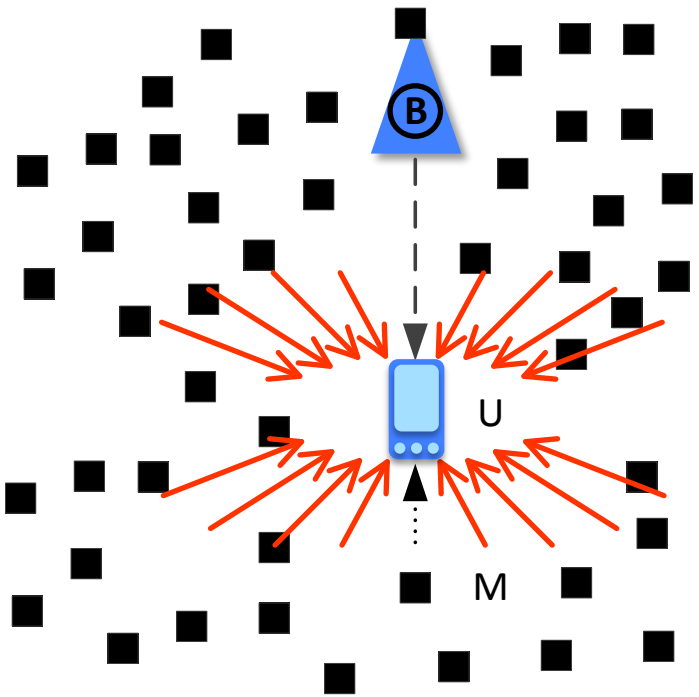
maximal R_B with single-user decoding

$$\Gamma_B = \frac{\gamma_B}{1+\Gamma_M(1+\gamma_B)}$$



maximal zero-outage R_B is lowered, there is a penalty due to single-user decoding

evaluation scenario

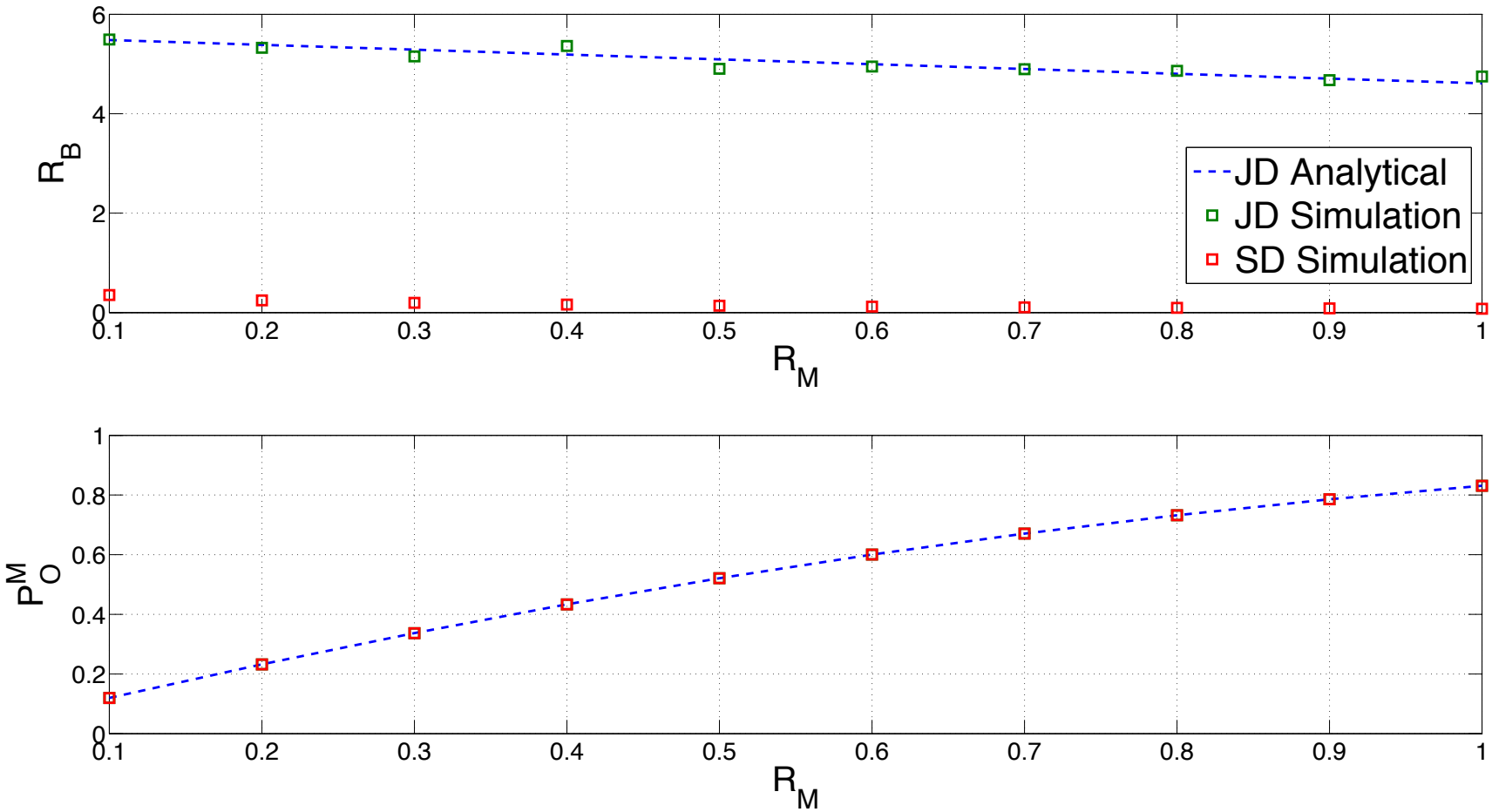


- U is the reference point
- M is uniformly distributed on a unit-radius circle centered at U
- B and NM-1 MTDs uniformly distributed within the disk of radius R

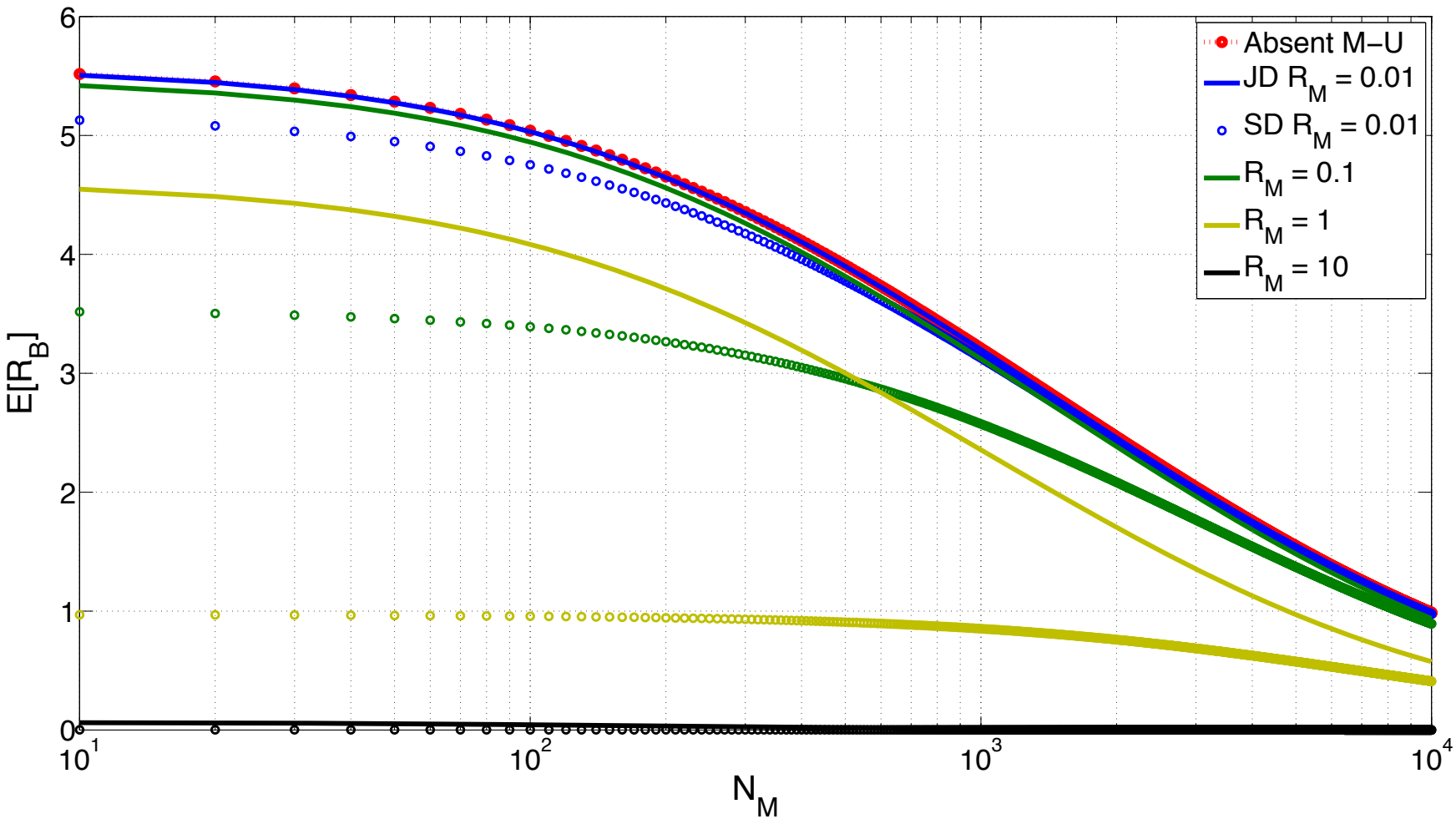
$\sigma^2 = -97.5$[dBm] $\alpha=4$ $R=200$[m]

$P_M = -10$[dBm] $P_B=30$[dBm]

numerical results



regime of high interference



summary

D2D will play multiple roles in 5G and improve

- reliability, latency, throughput per area, spectral efficiency,

machine-type access

we have considered underlay D2D for

low-power low-rate machine access

- outage-free transmission even in presence of underlay
- keys: low rate and successive interference cancellation

next steps

- evaluate the concept with actual modulation/coding
- D2D for trunking in M2M access