

Class Note

- 作业提交至邮箱
 - dianzidaolun@163.com
- 命名规则
 - 老师姓名-学生姓名
- **Deadline: 19周之前**
- **3000字左右**

电子信息技术导论

无线通信之频谱共享

王玺钧



Spectrum matters
because **communications matters**



Spectrum **sharing matters because
communications **spectrum** is a **scarce** asset
and **demand** is **growing** very fast**



**Wireless and mobile communications
now dominate
all communications globally**

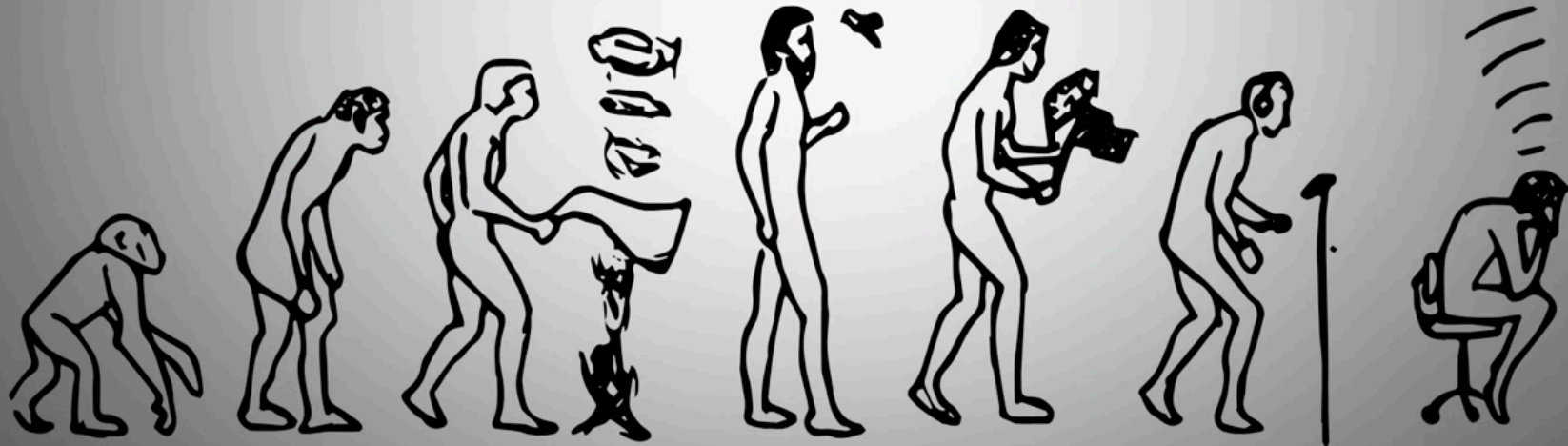
It all begins with ...

Cavemen





HISTORY OF COMMUNICATION

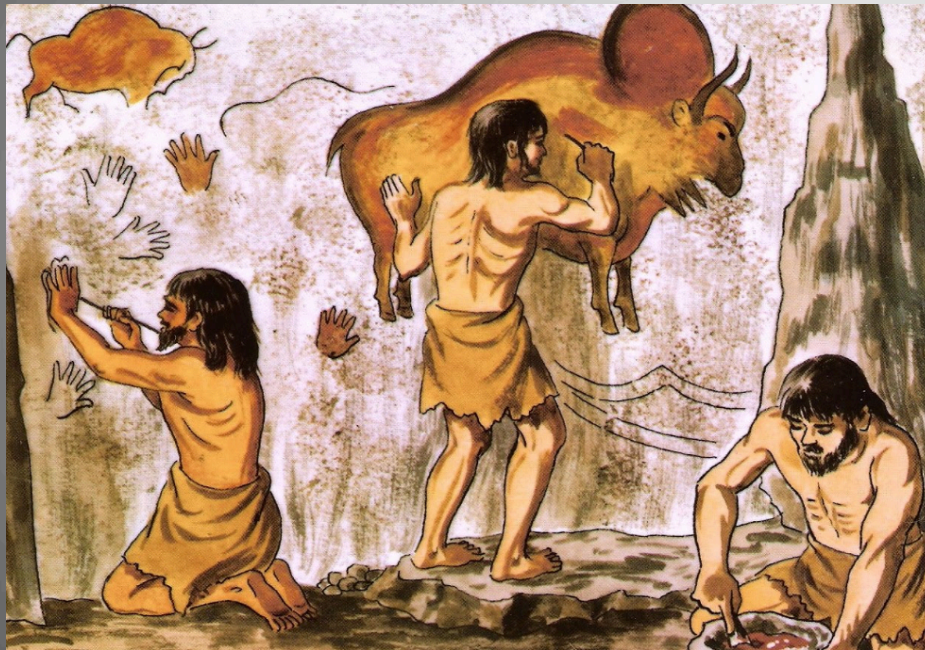


Cavemen



Cavemen

CAVEMEN STARTED INSCRIBING ON CAVES



BLOGGING



The Problem is ...

Localized Communication



When cavemen moved out the cave...

Long-distance communication



Smoke Signal

USED BY -

TRIBES OF NORTH AMERICA



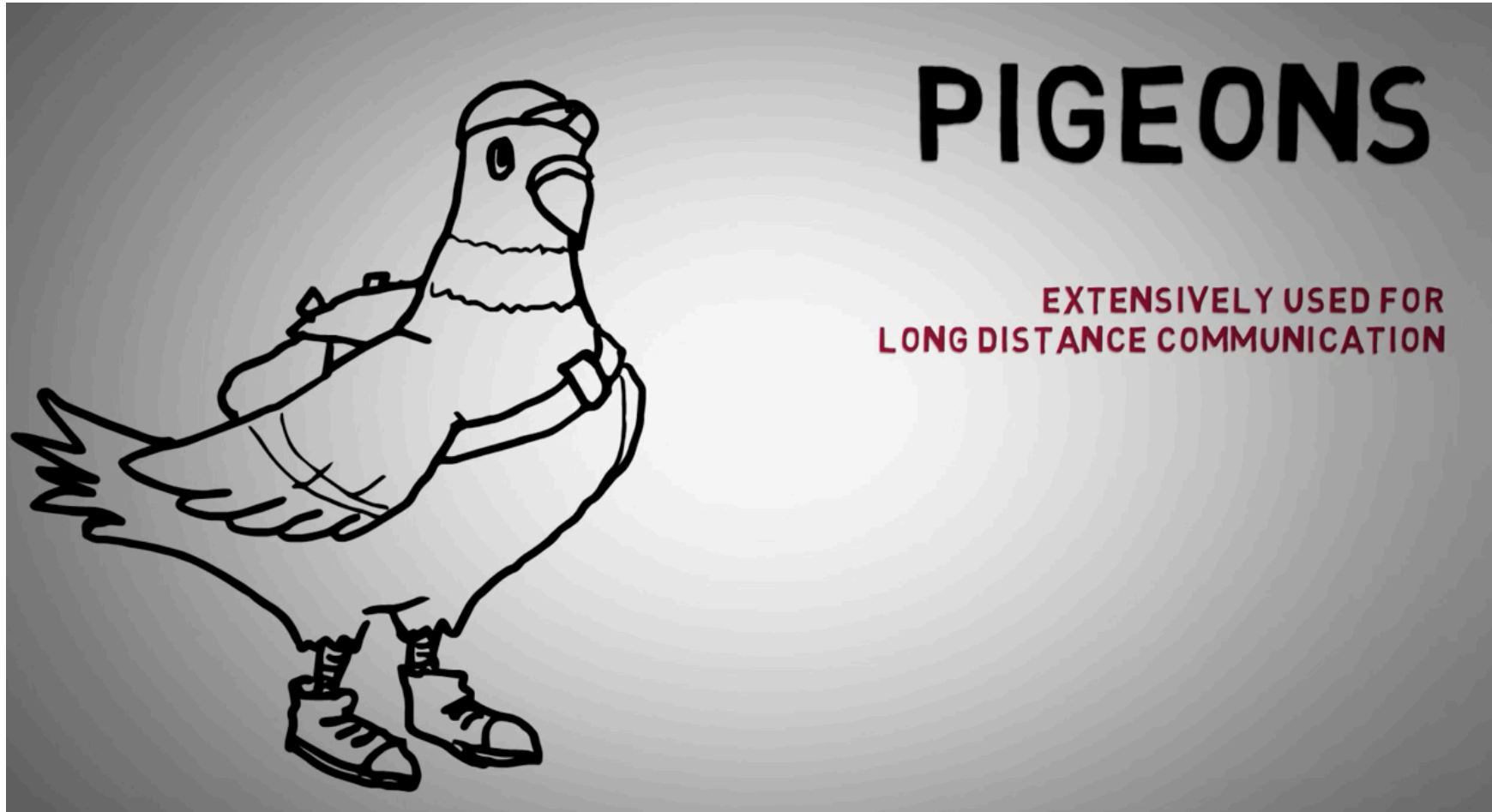
Smoke Signal

- as far away as 750 kilometers in just a few hours





Pigeons



PIGEONS

EXTENSIVELY USED FOR
LONG DISTANCE COMMUNICATION



Raven



Pony Express



“驿寄梅花，鱼传尺素，砌成此恨无重数”

Semaphore Flag





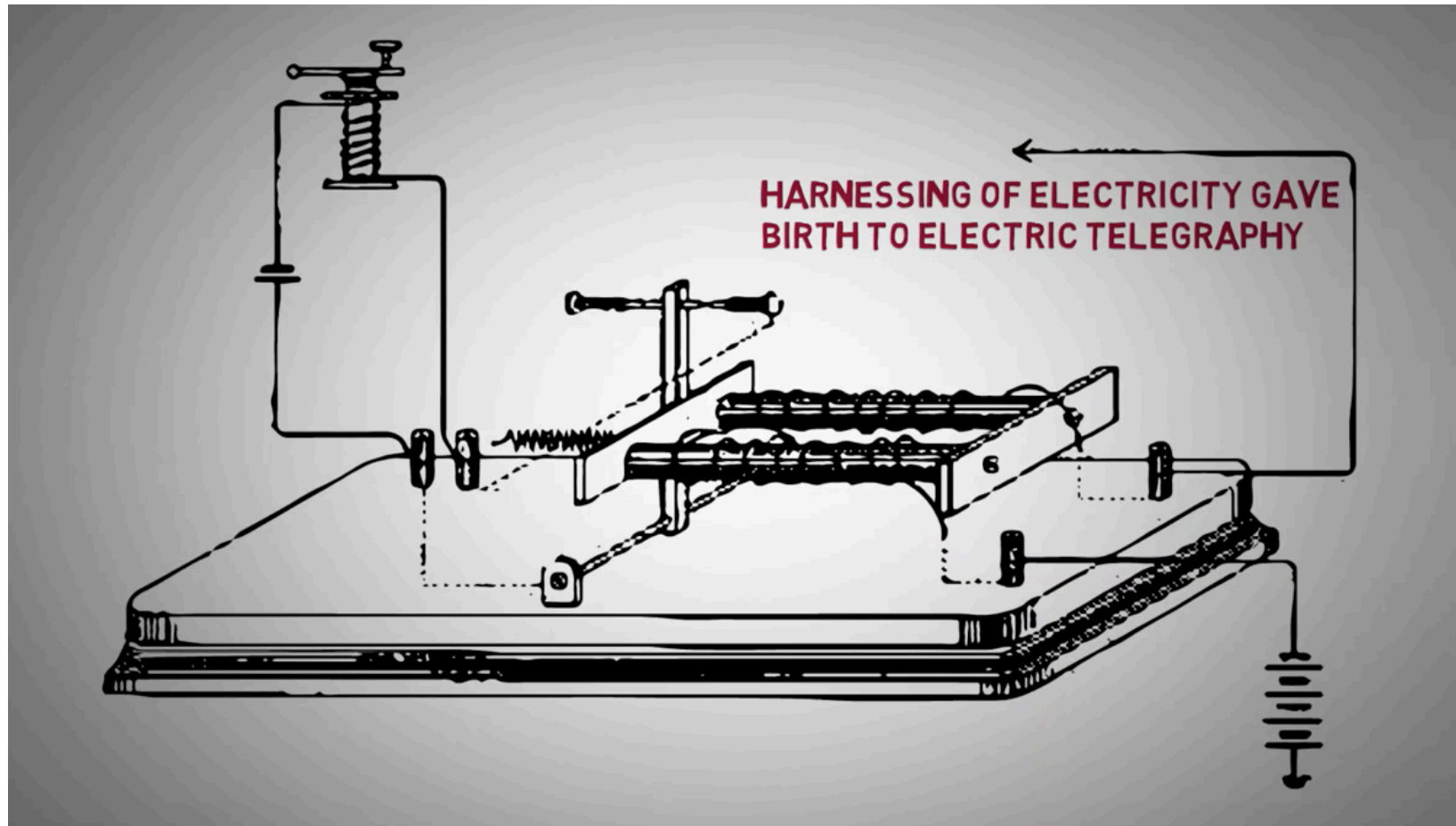
Semaphore Flag

ACCEPTABLE MODE OF COMMUNICATION
FOR
EMERGENCY

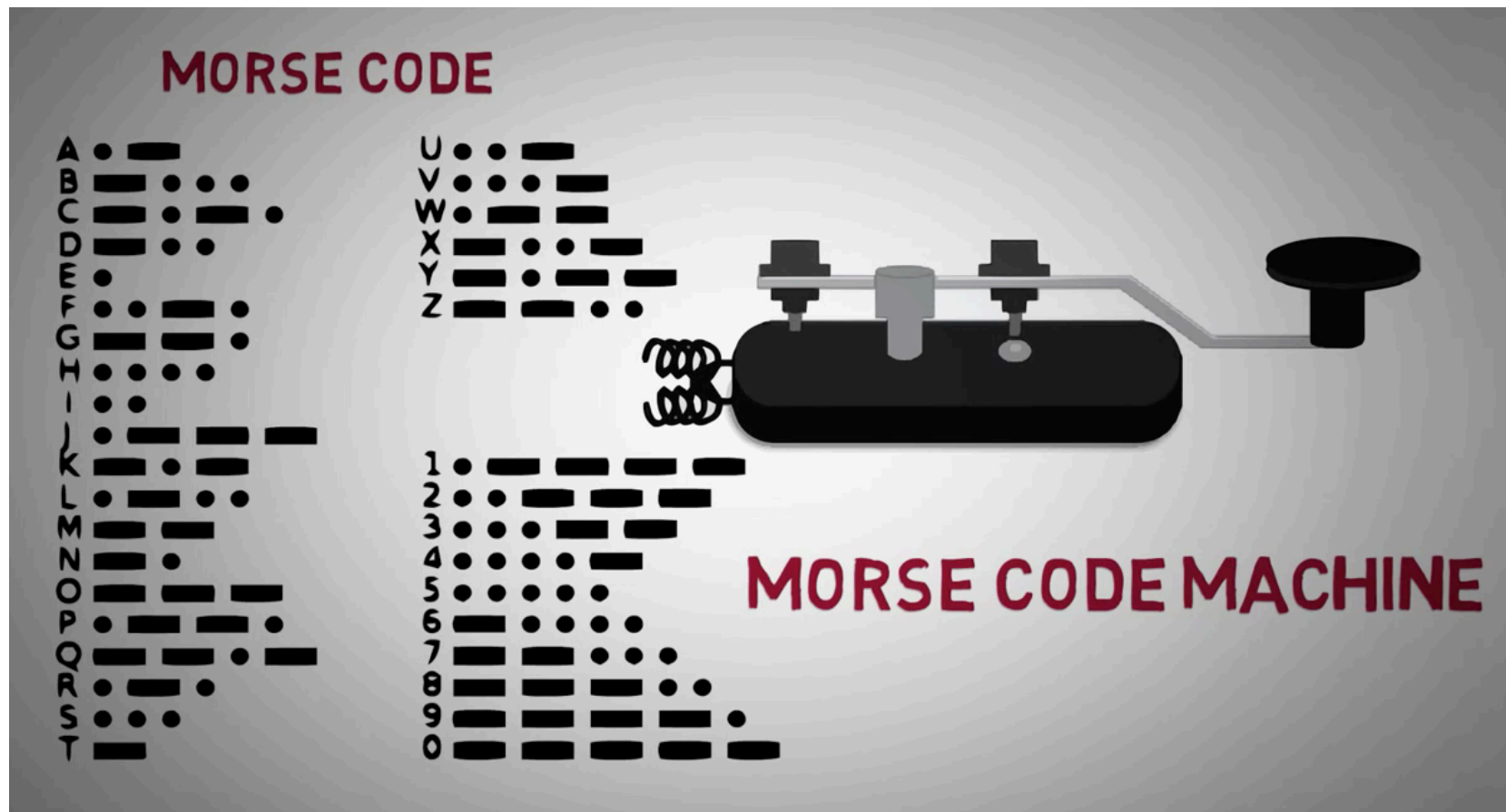




Telegraph



Morse Code





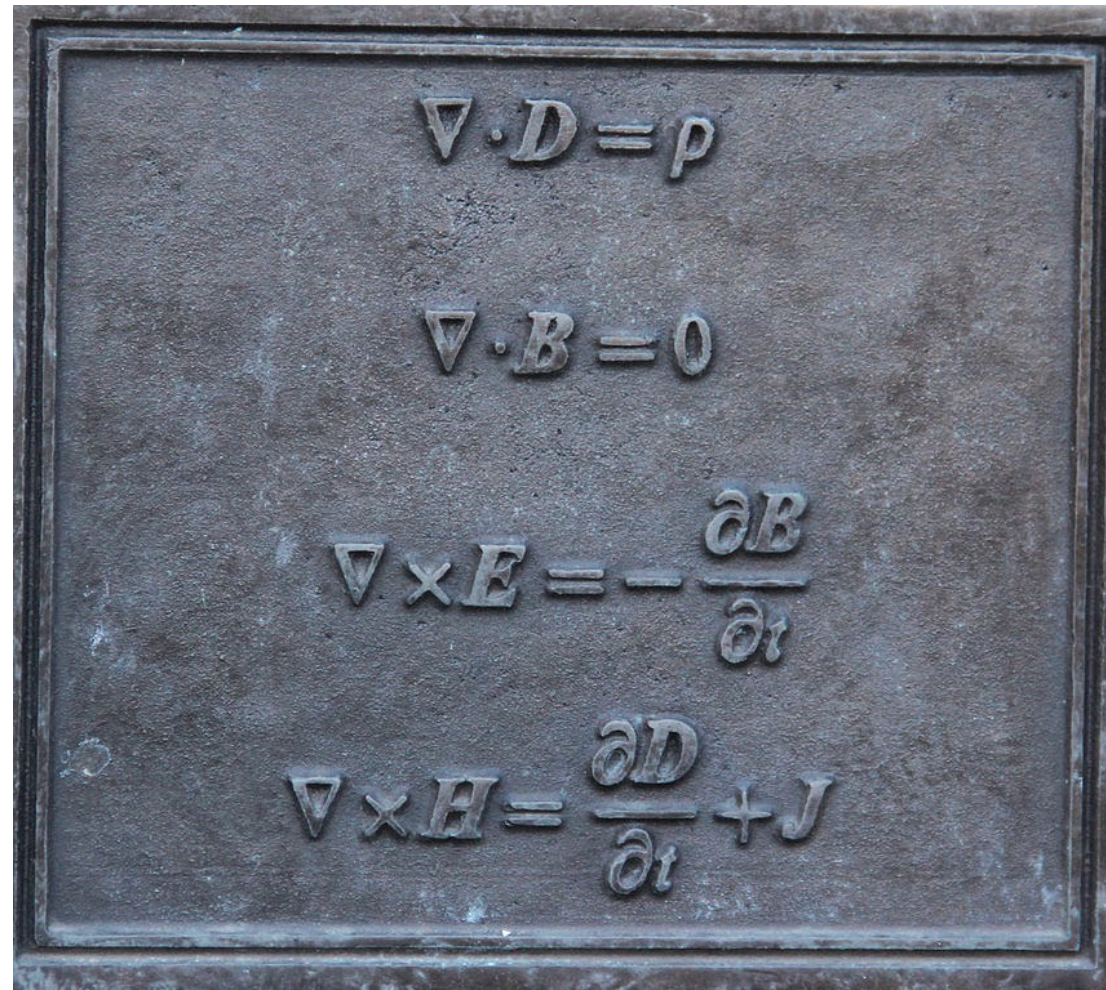
Radio

RADIO

1864 - JAMES CLERK MAXWELL

MATHEMATICALLY PROVED -
EXISTANCE OF EM WAVE IN FREE SPACE

Maxwell's Equations





Radio

RADIO

1886 - HEINRICH HERTZ

mHz

kHz

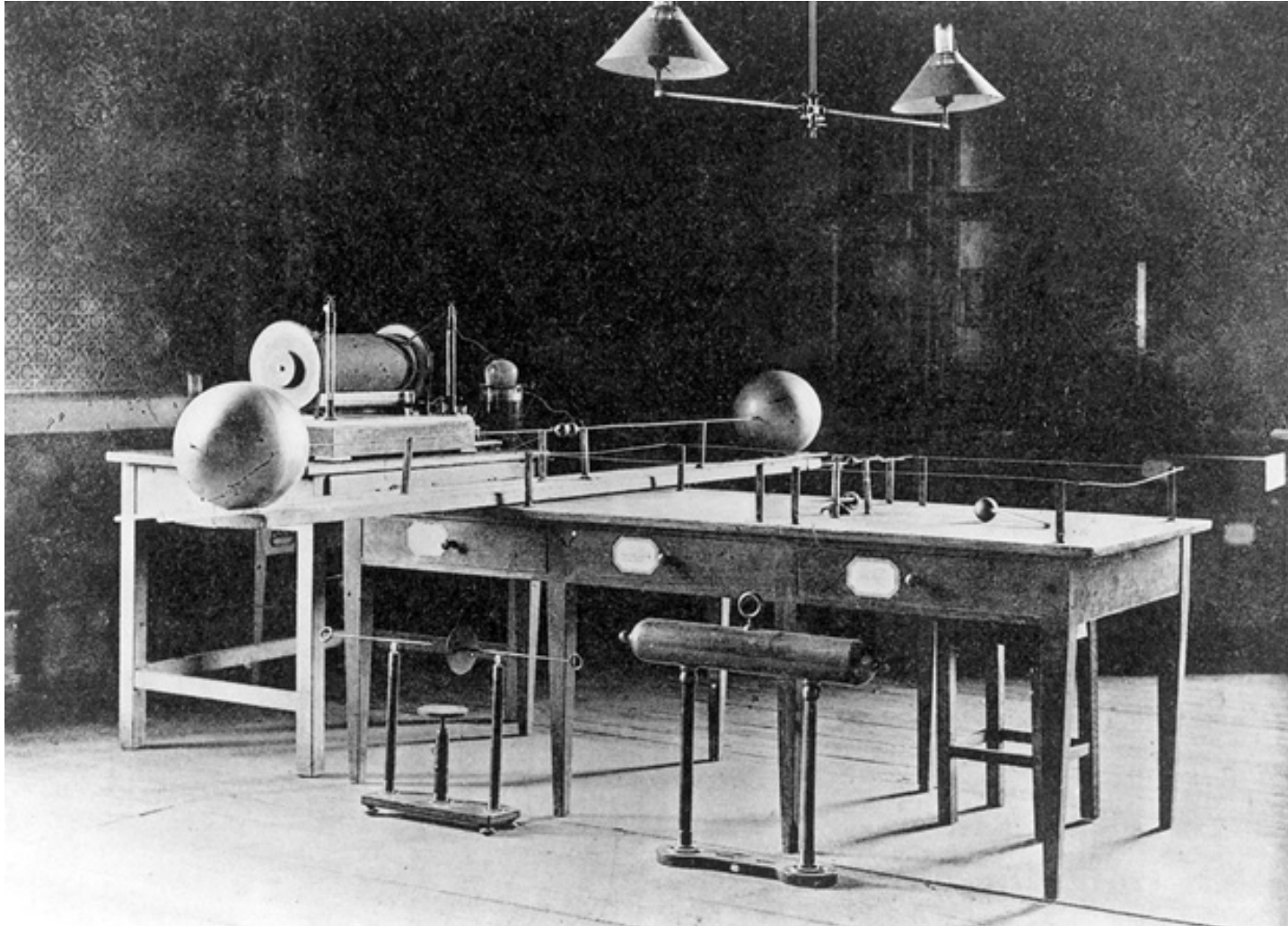
IN 1888
DEMONSTRATED
RADIO WAVES

ESTABLISHED
THE EXISTENCE OF ELECTROMAGNETIC WAVES

The infographic features a portrait of Heinrich Hertz on the left, with a sine wave below it. A green arrow points from the word 'RADIO' towards a vertical line representing a radio antenna. To the right of the antenna, a beam of light is shown emanating from a lamp-like structure, symbolizing the transmission of radio waves. The background consists of concentric circles radiating from the antenna, representing the propagation of electromagnetic waves.



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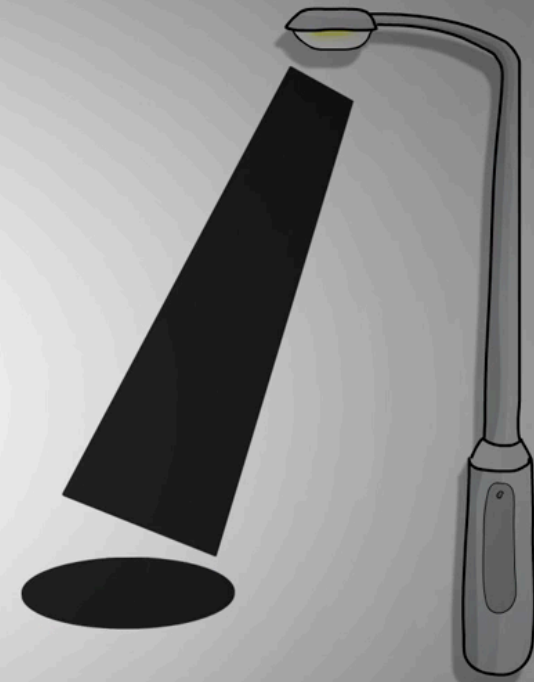
RADIO

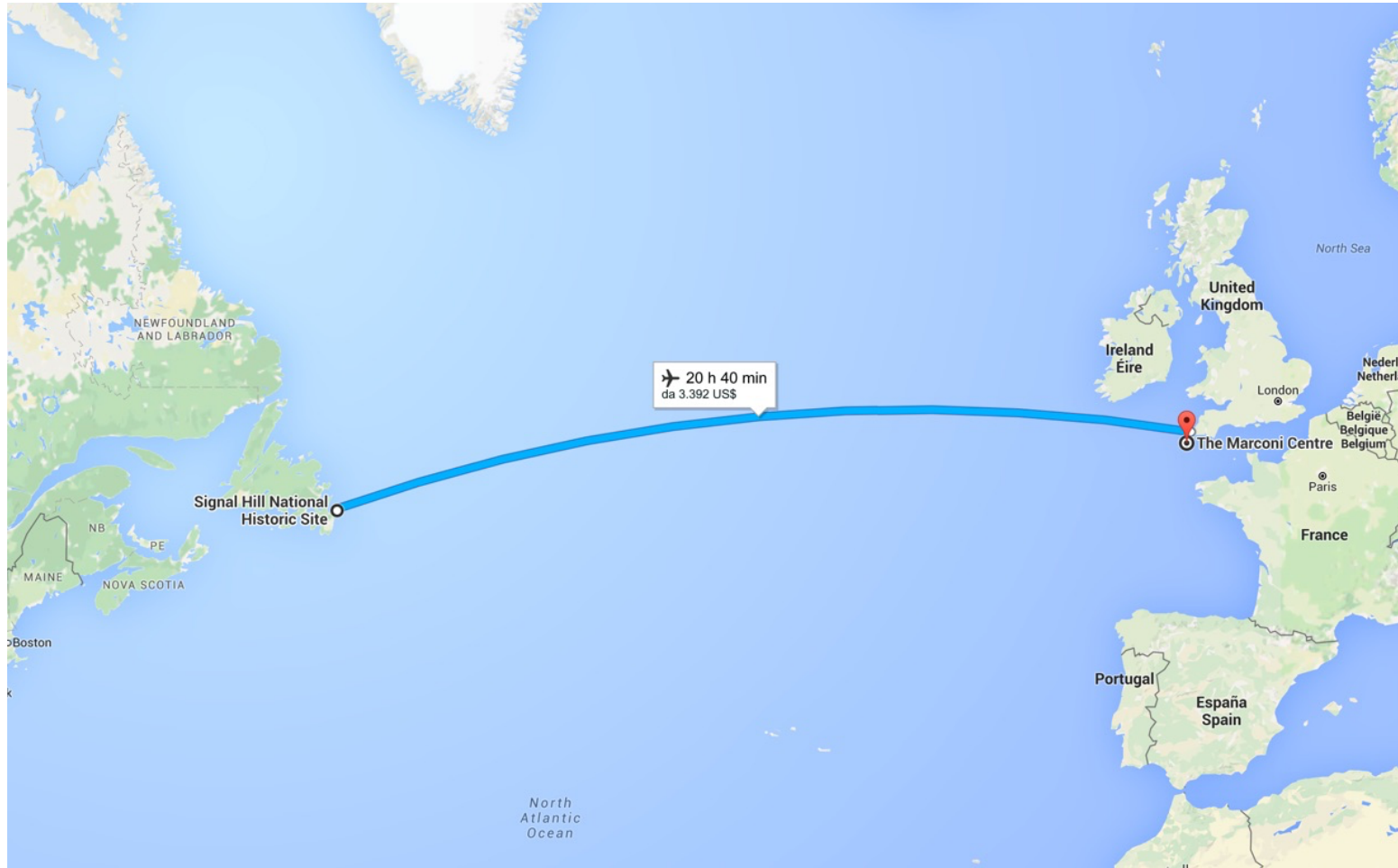


1894 - GUGLIELMO MARCONI



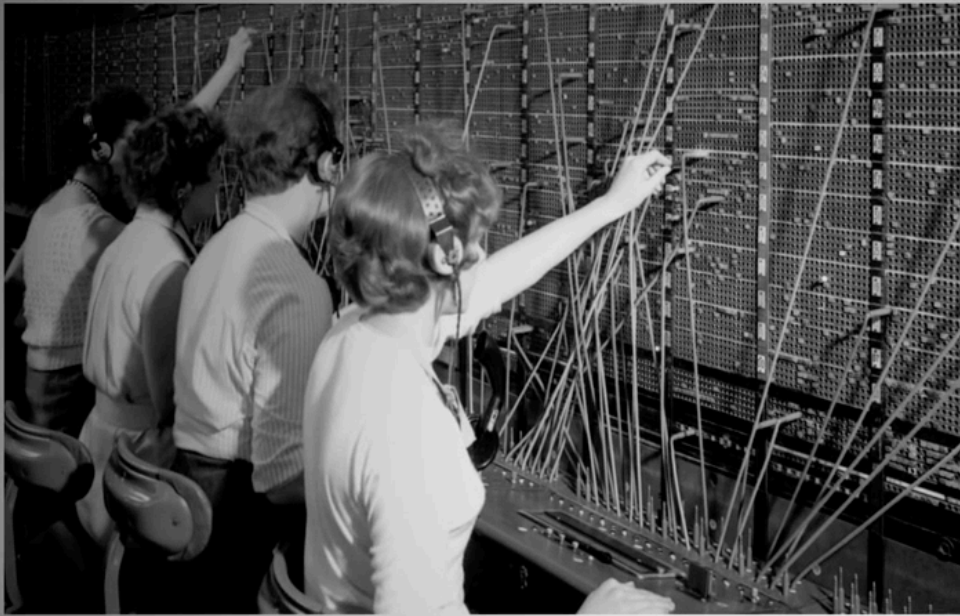
BEGINNING OF NEW ERA OF
DISTANT COMMUNICATION





Telephone

□ Real-time communication



1876 ALEXANDER GRAHAM BELL



TELEGRAM WAS THE FASTEST
ONE TO ONE COMMUNICATION USED
BY COMMON PEOPLE

USED FOR DIPLOMATIC PURPOSE OR BROADCASTING

TELEPHONE

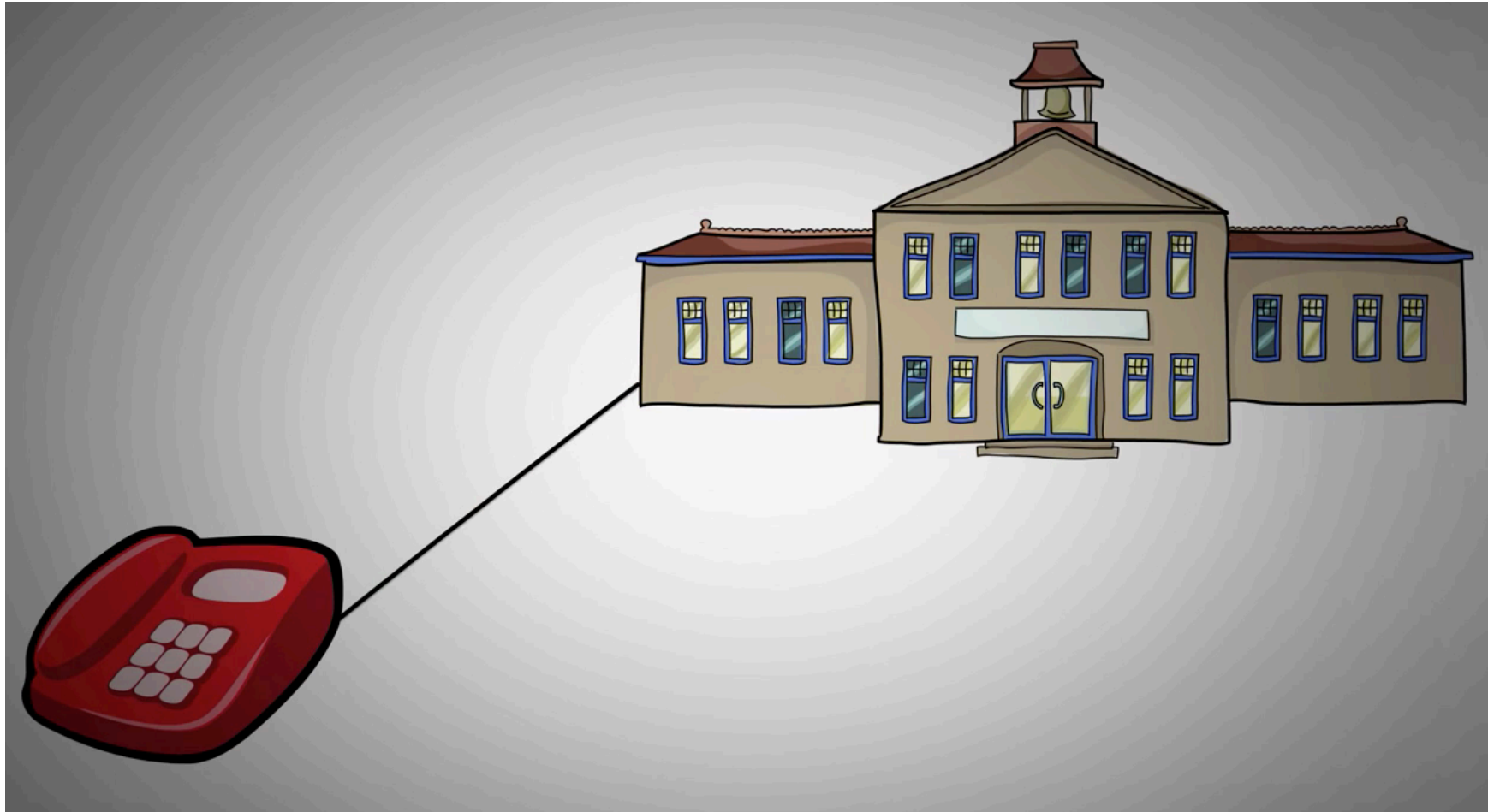


Dedicated line



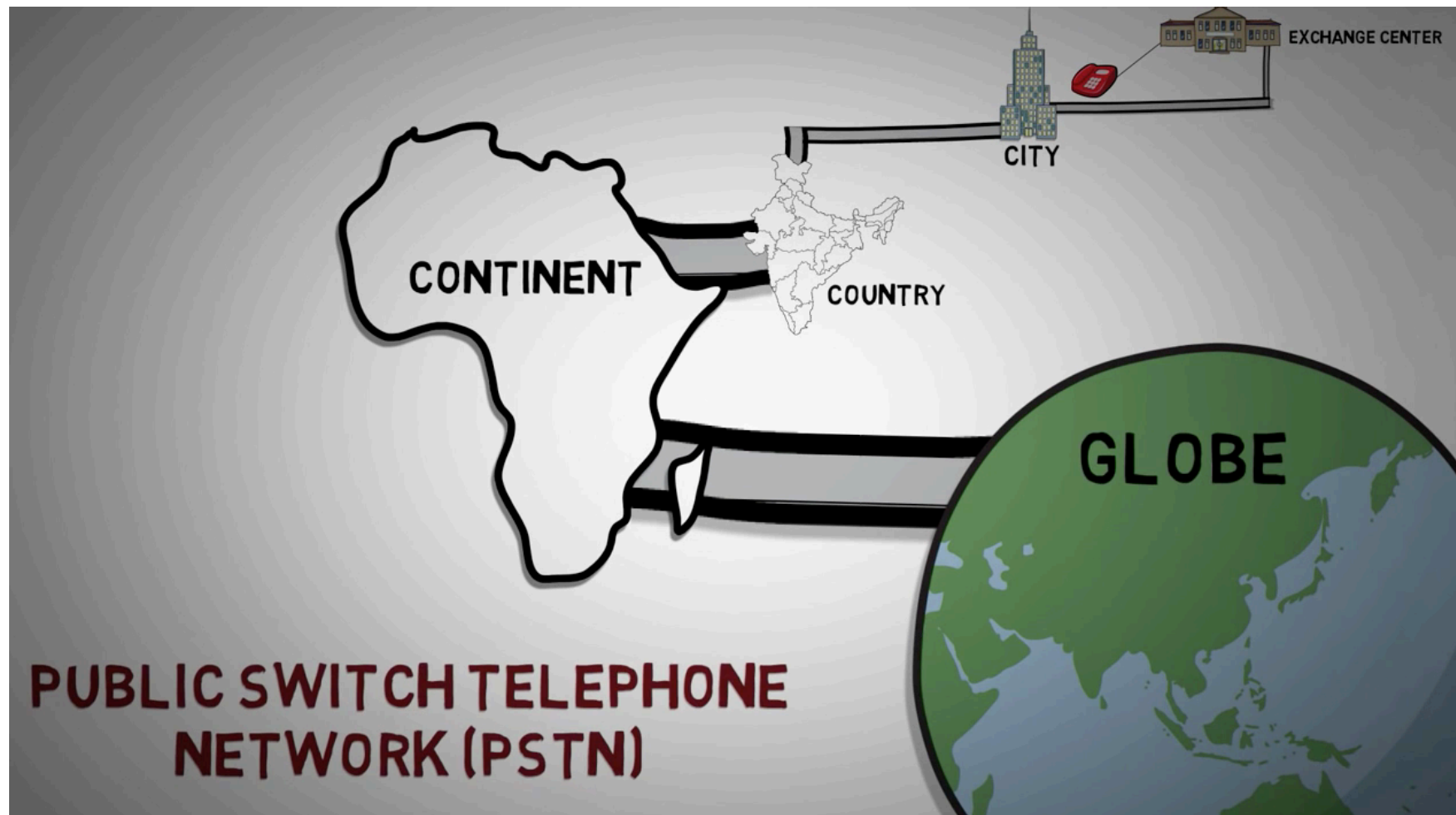


Switch





PSTN



Evolution

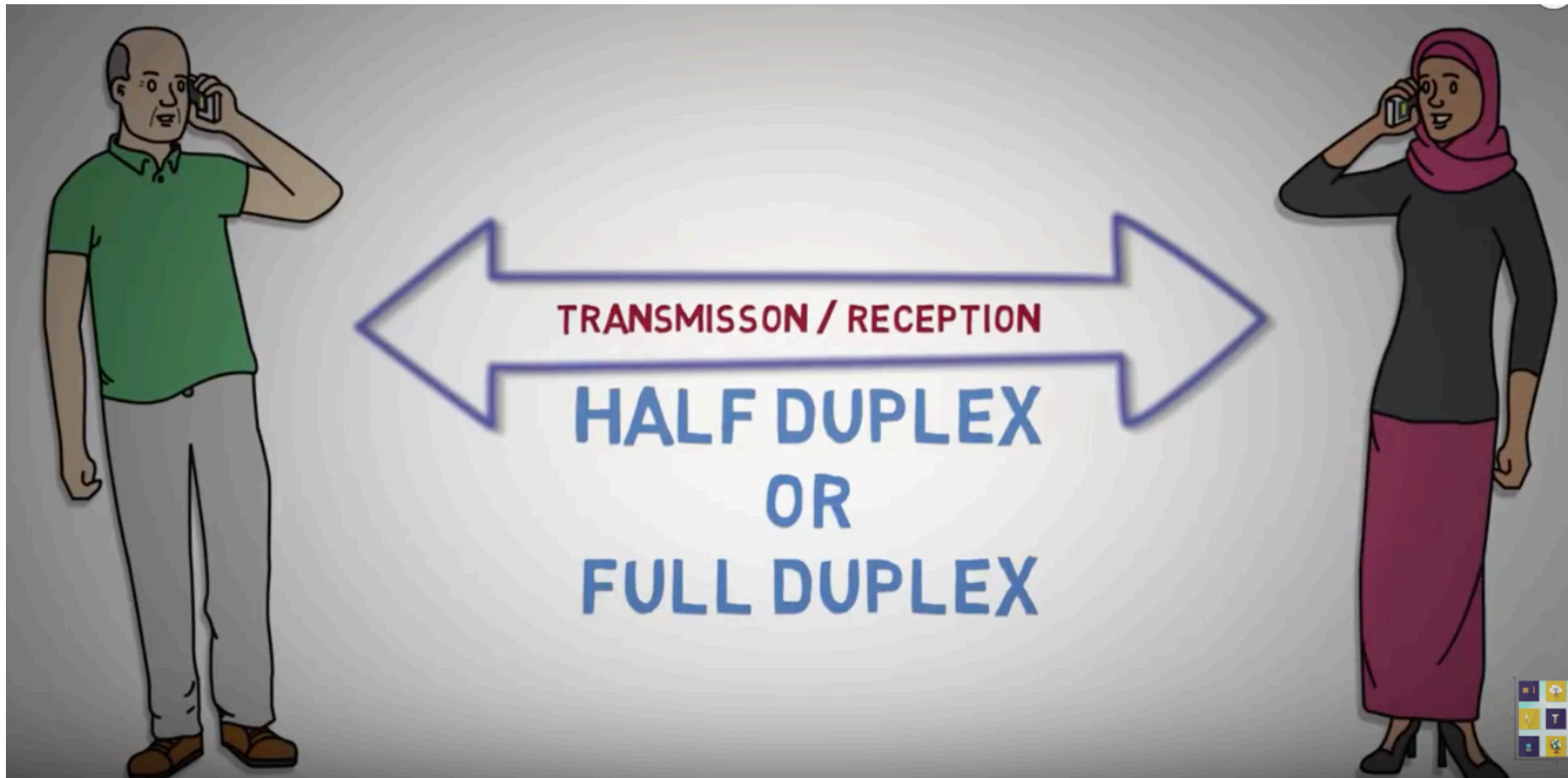




Spectrum sharing between a transmitter & a receiver

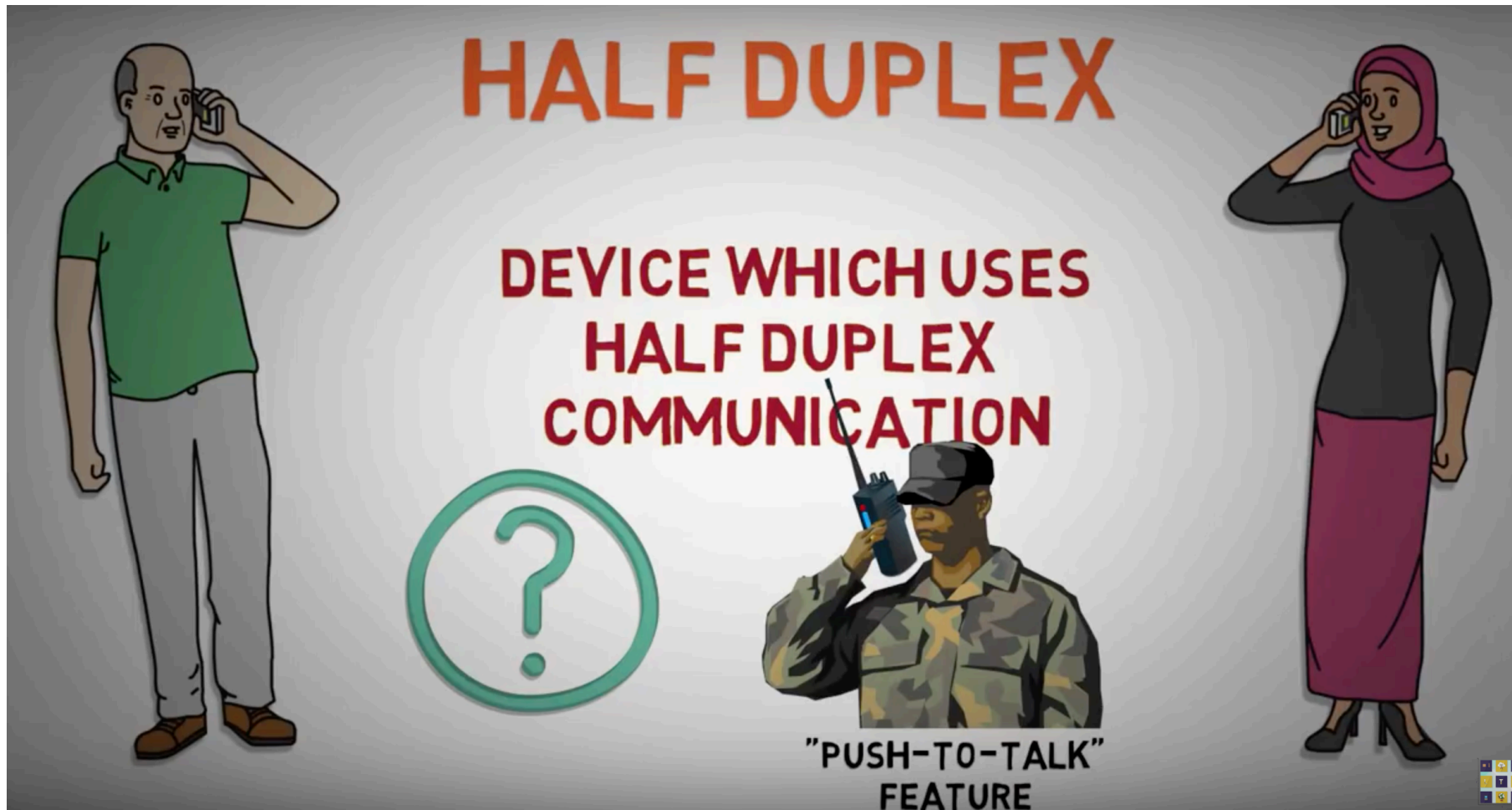


Duplexing



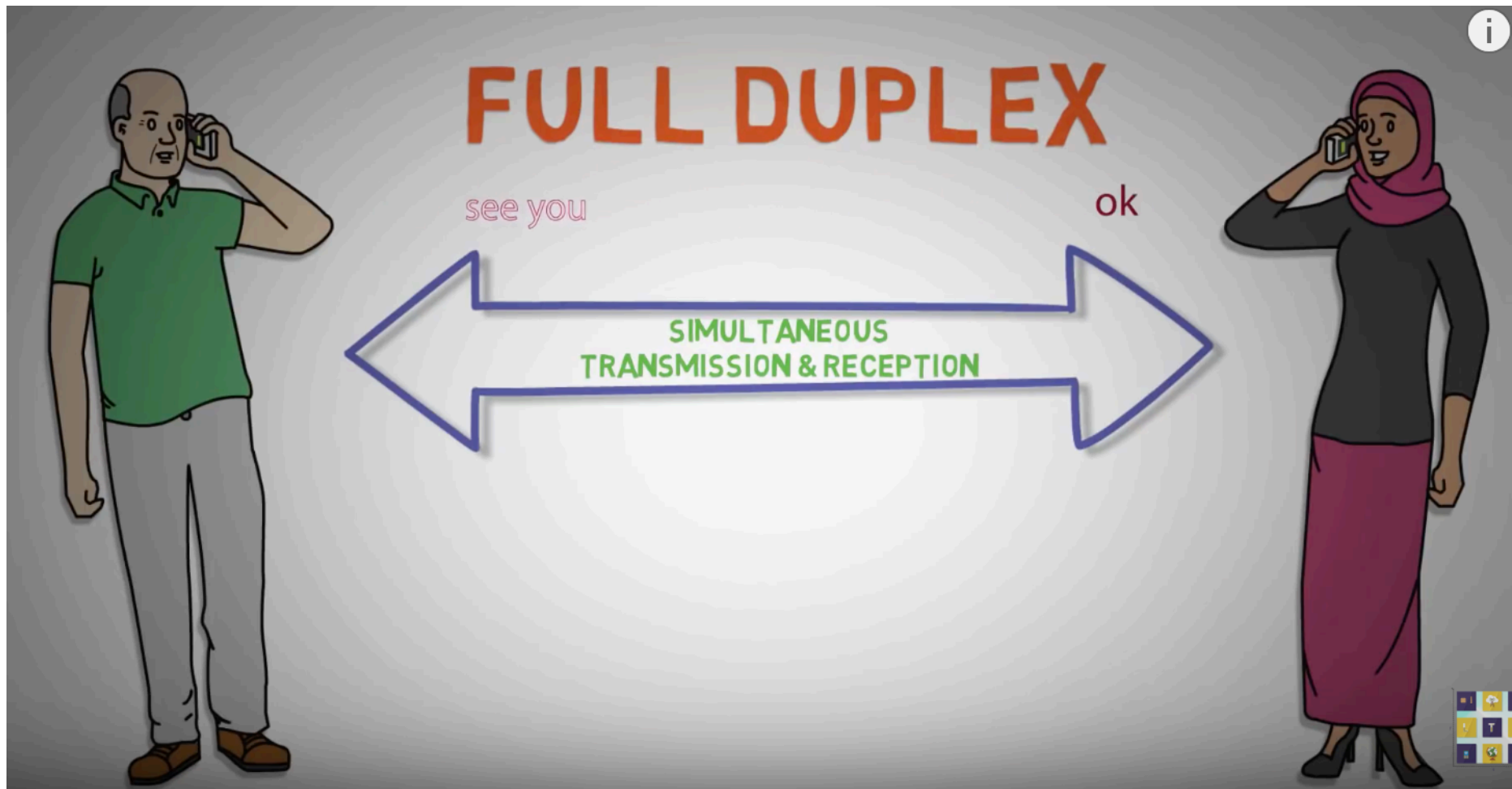
Half Duplex

- One way communication at a time



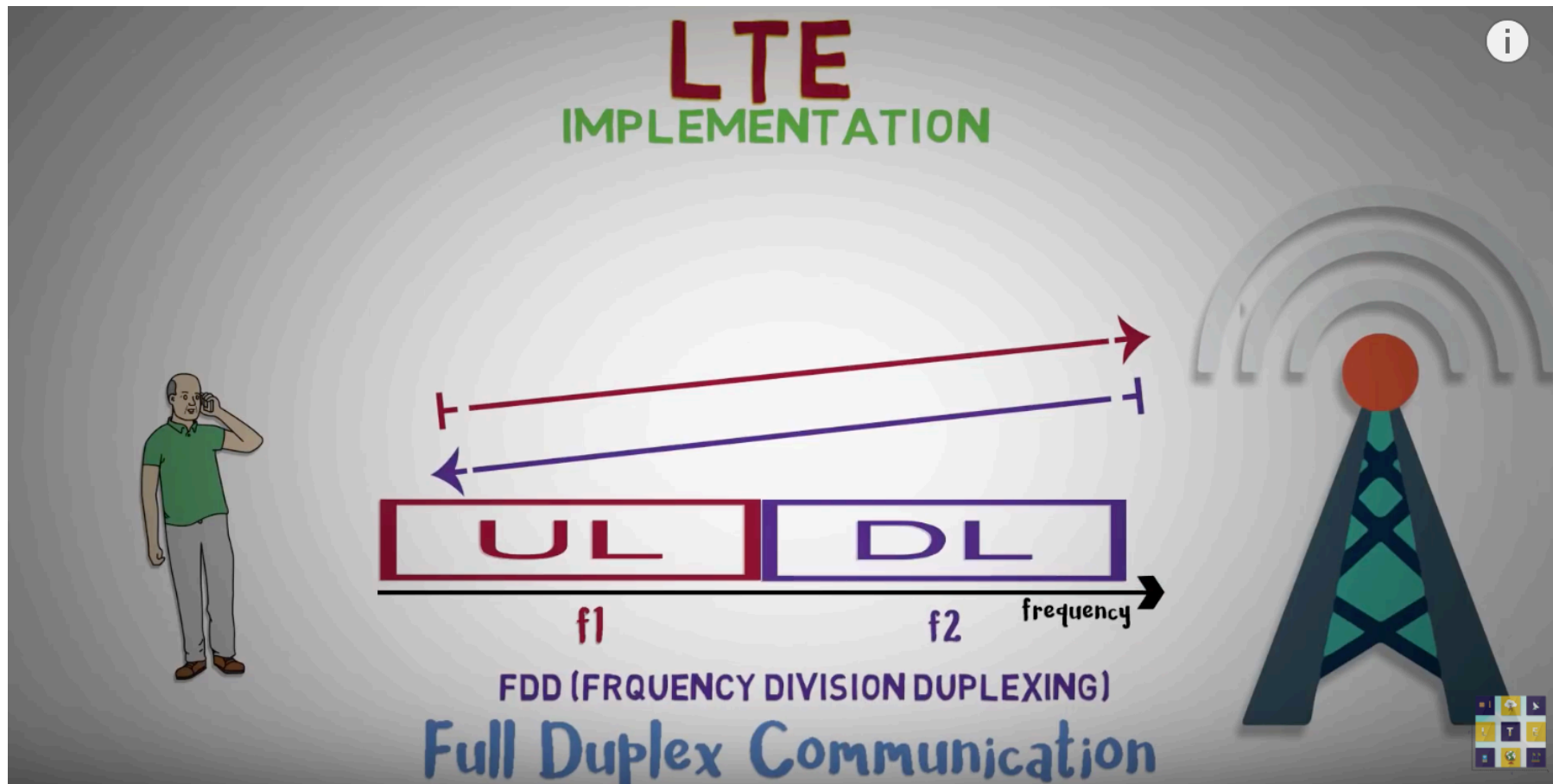
Full Duplex

- Two way communication



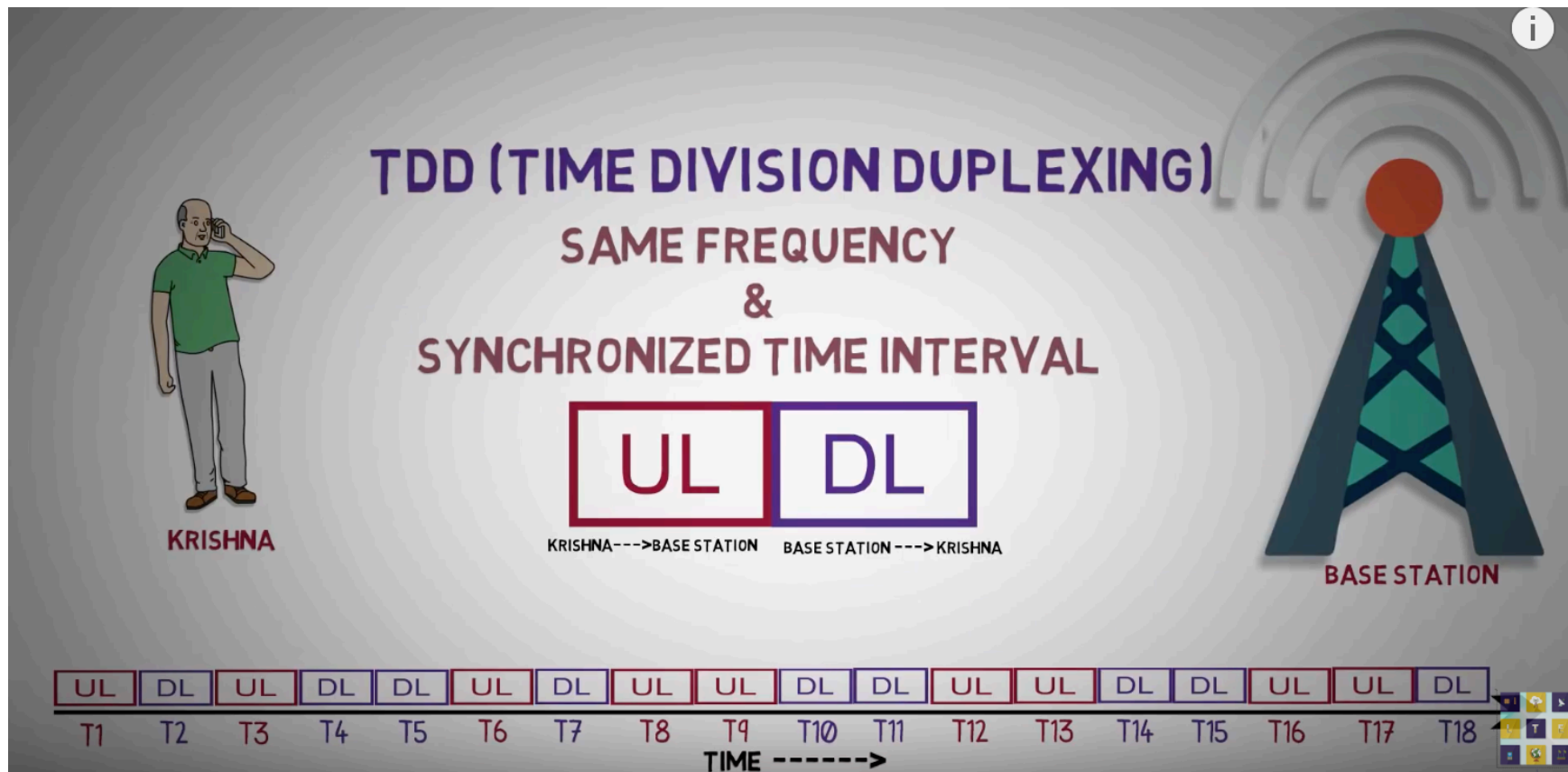
Full Duplex

□ FDD

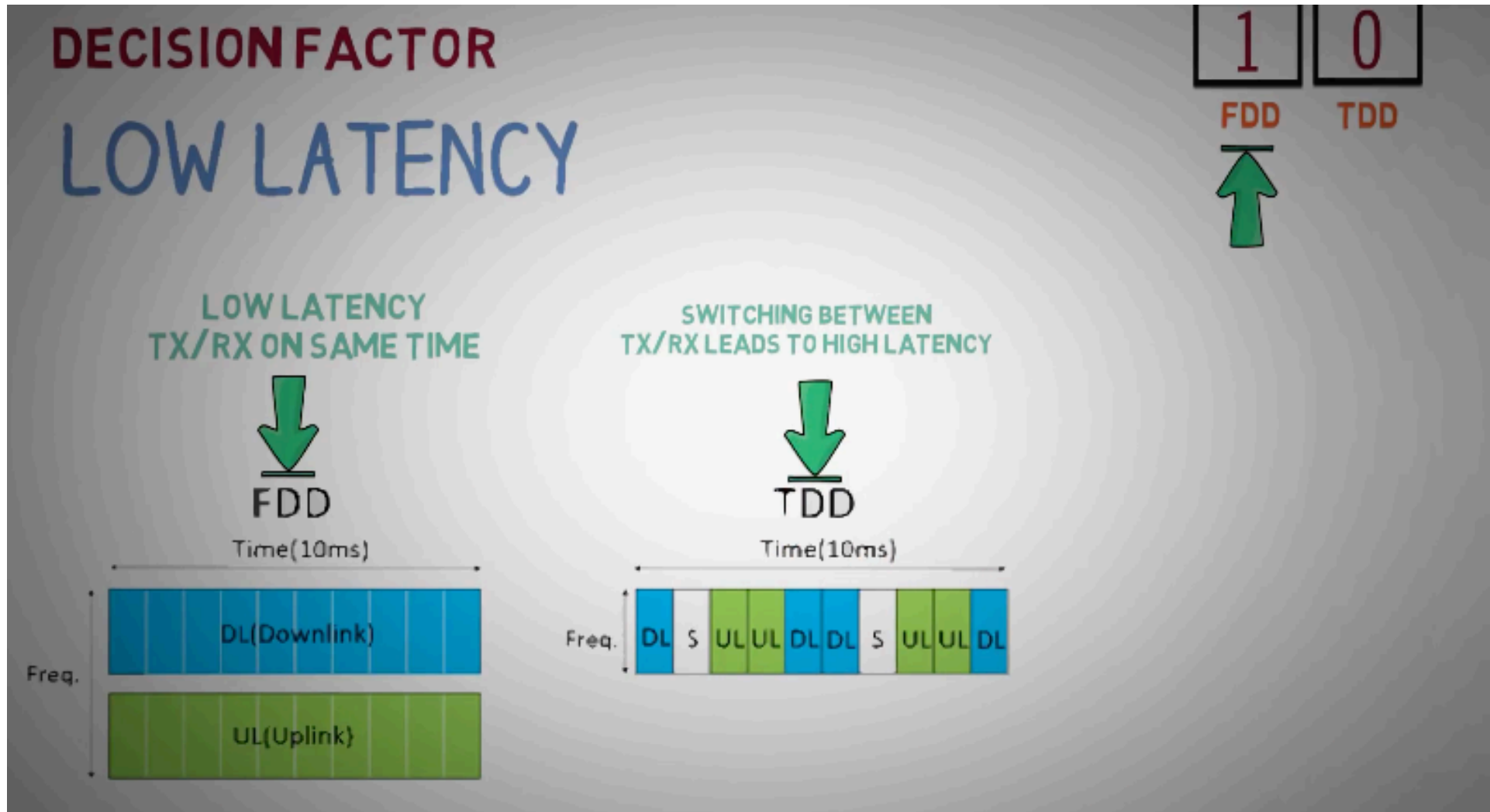


Full Duplex

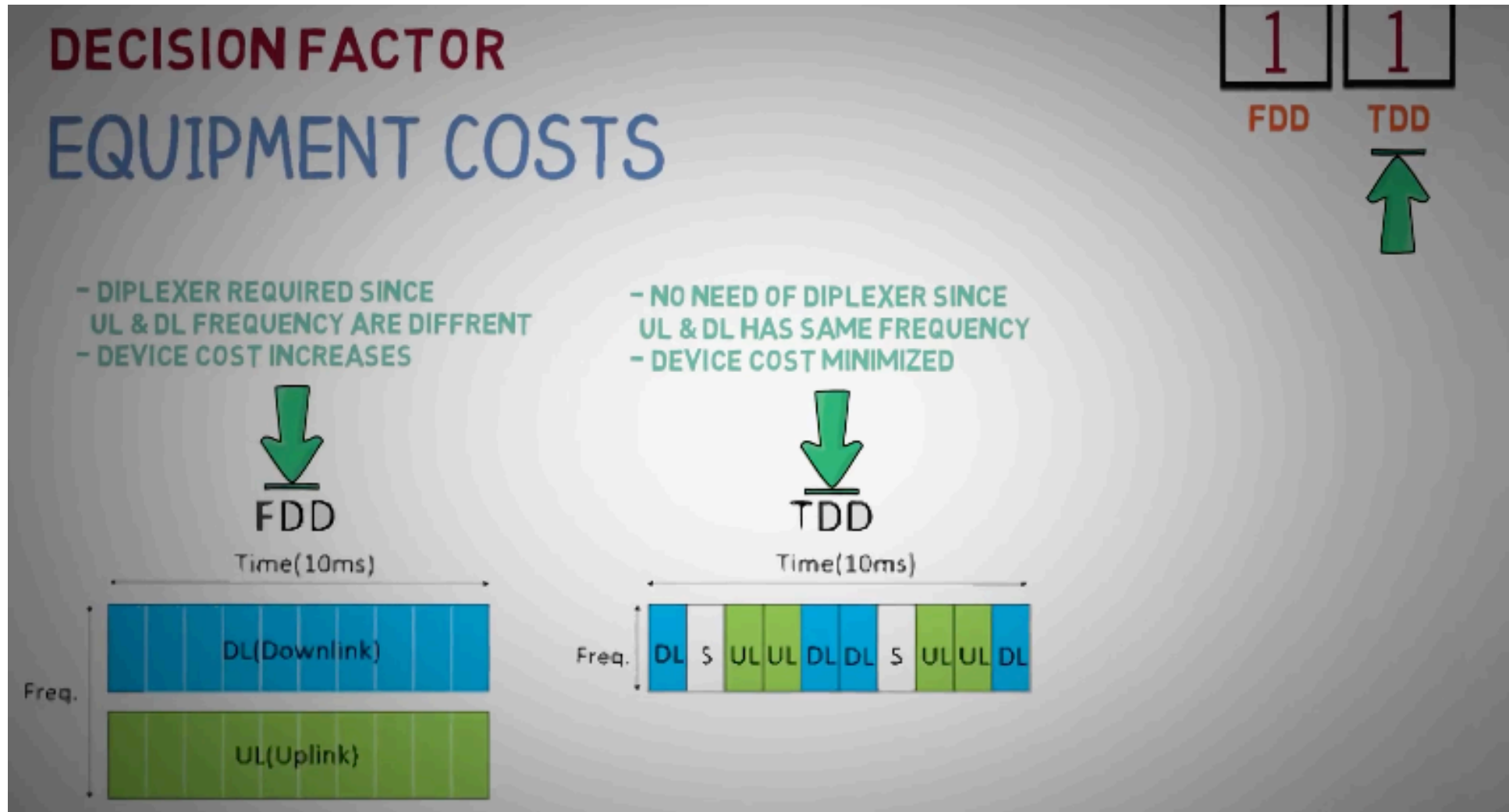
□ TDD



FDD or TDD?



FDD or TDD?



FDD or TDD?

DECISION FACTOR

DISTANCE PREFERABILITY

2	1
FDD	TDD

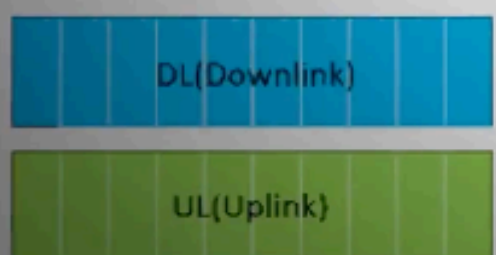
↑

- TRANSMISSION TAKES PLACE IN SAME TIME
- EFFICIENCY UNAFFECTED IN COMPARE TO TDD

↓

FDD

Time(10ms)




- GUARD PERIOD PROPORTIONAL TO DISTANCE
- EFFICIENCY REDUCED

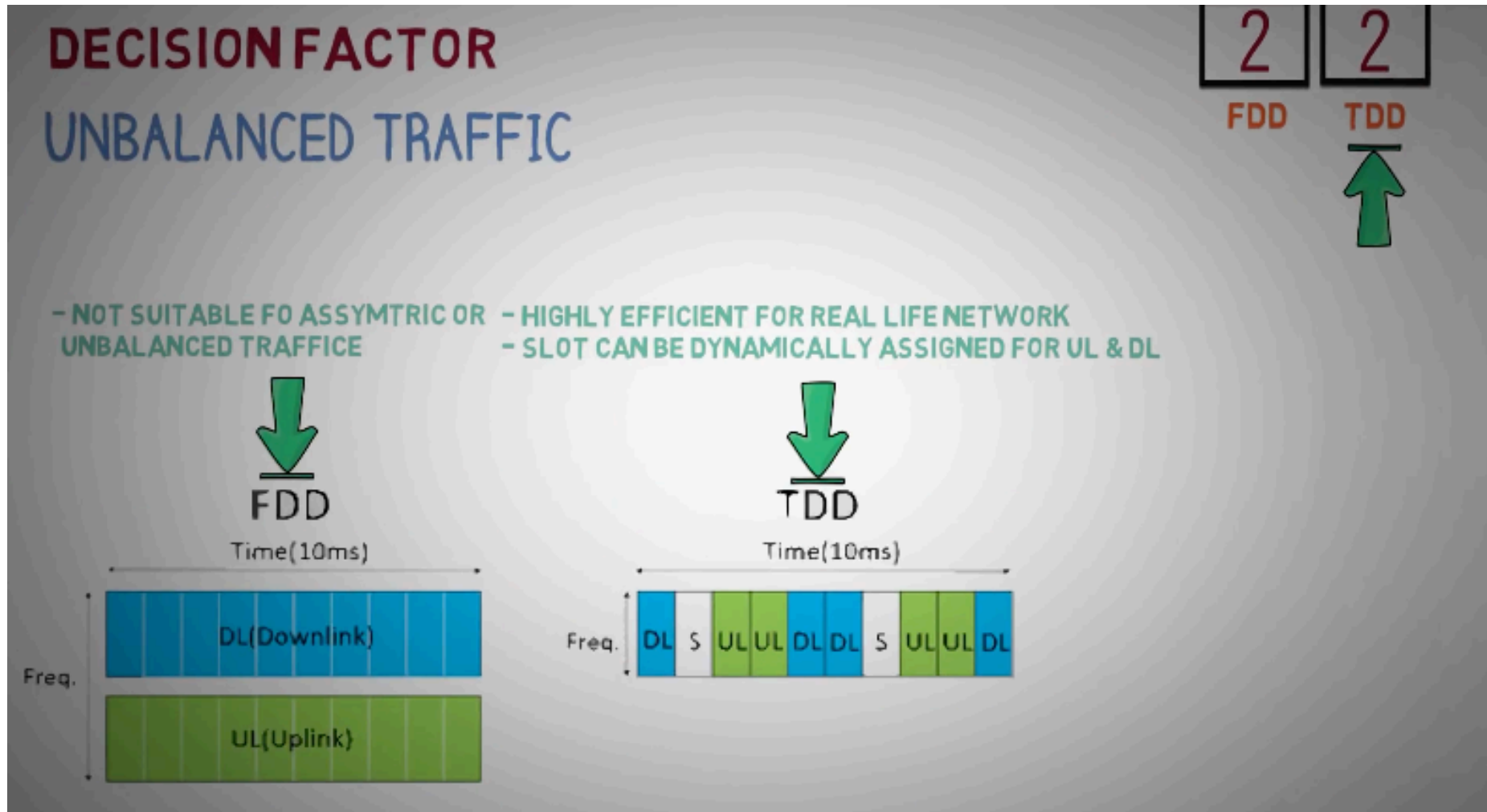
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TDD

Time(10ms)



FDD or TDD?



FDD or TDD?

DECISION FACTOR SPECTRAL EFFICIENCY

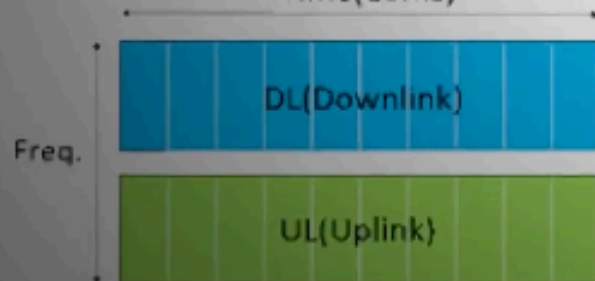


- FREQUENCY DIVIDED INTO UL & DL,
SPECTRAL EFFICIENCY REDUCED



FDD

Time(10ms)

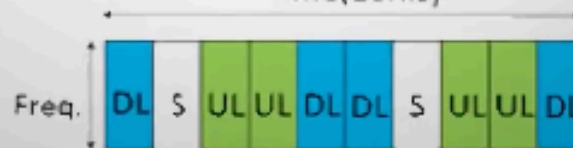


- USED SINGLE FREQUENCY LEADS TO
HIGH SPECTRAL EFFICIENCY

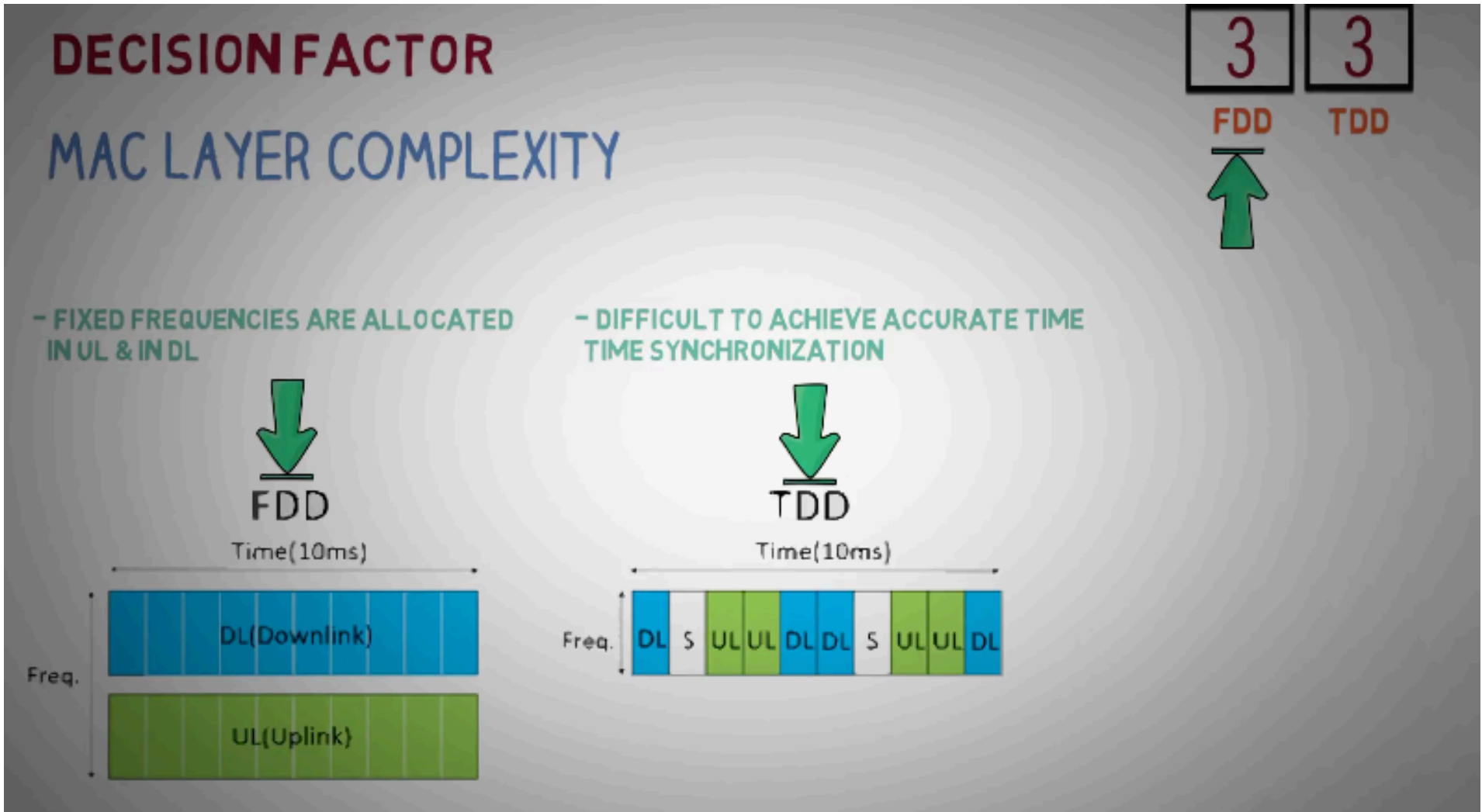


TDD

Time(10ms)



FDD or TDD?





How does it work?



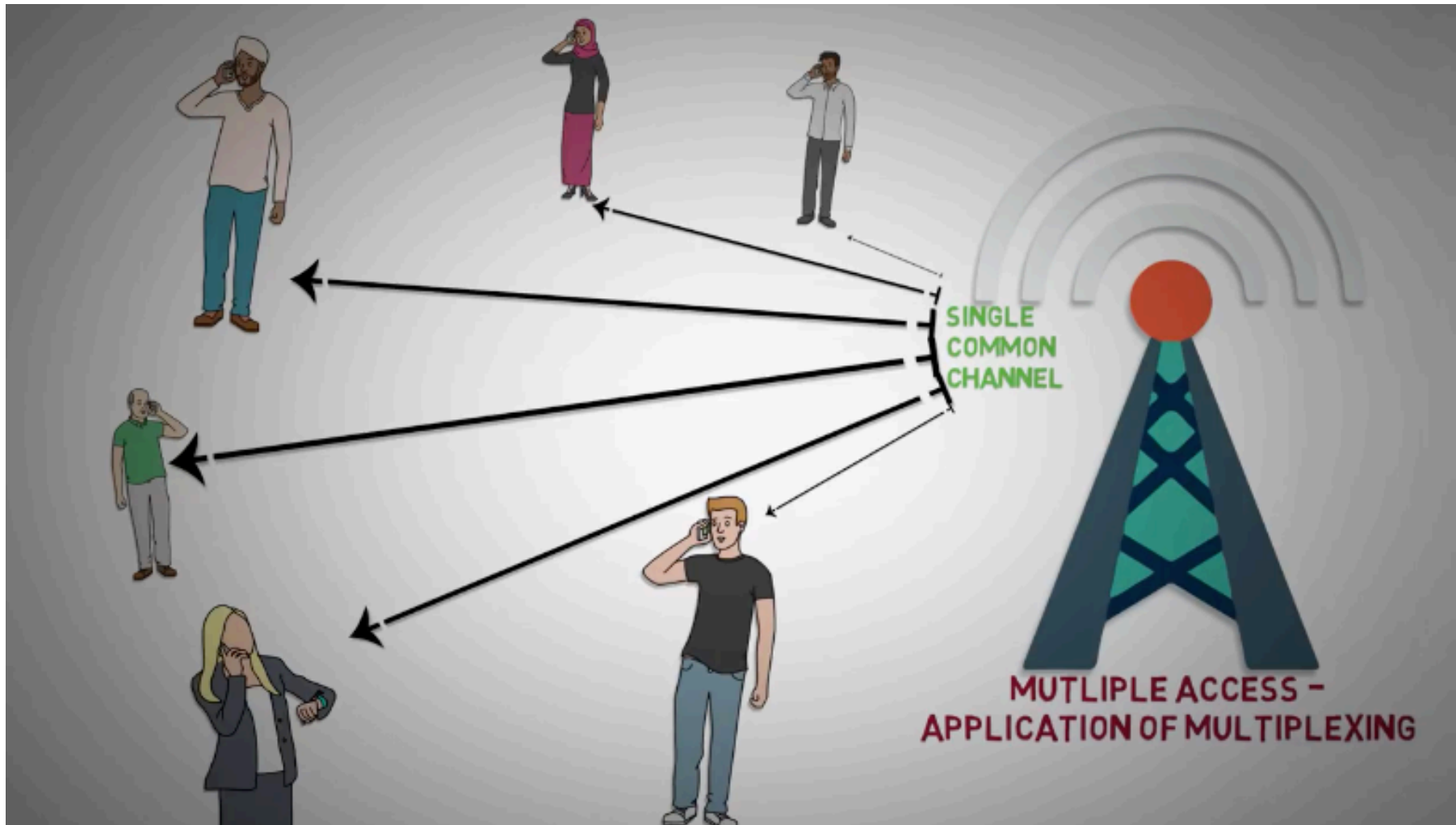


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Spectrum sharing between multiple users

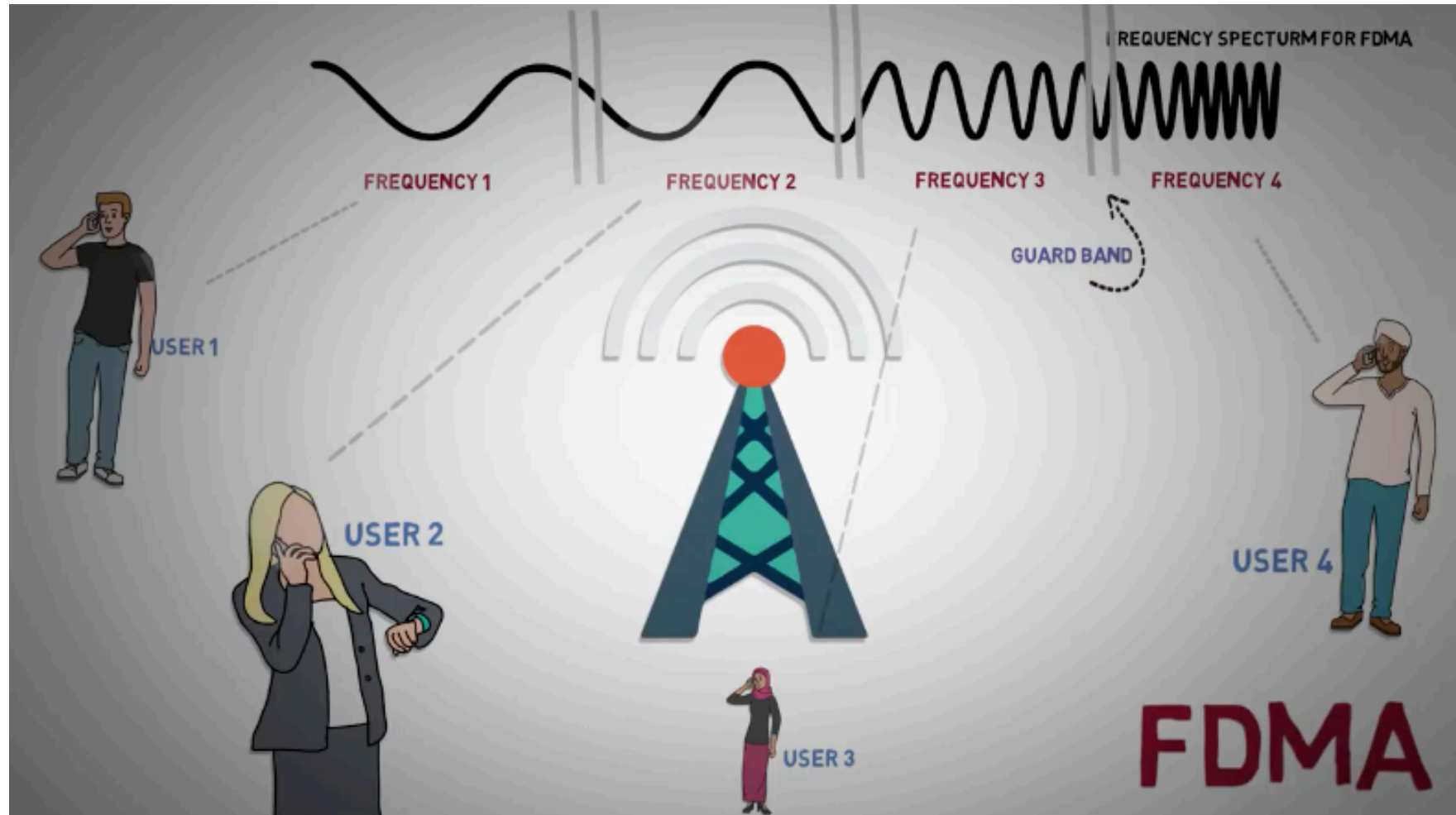


Multiple Access



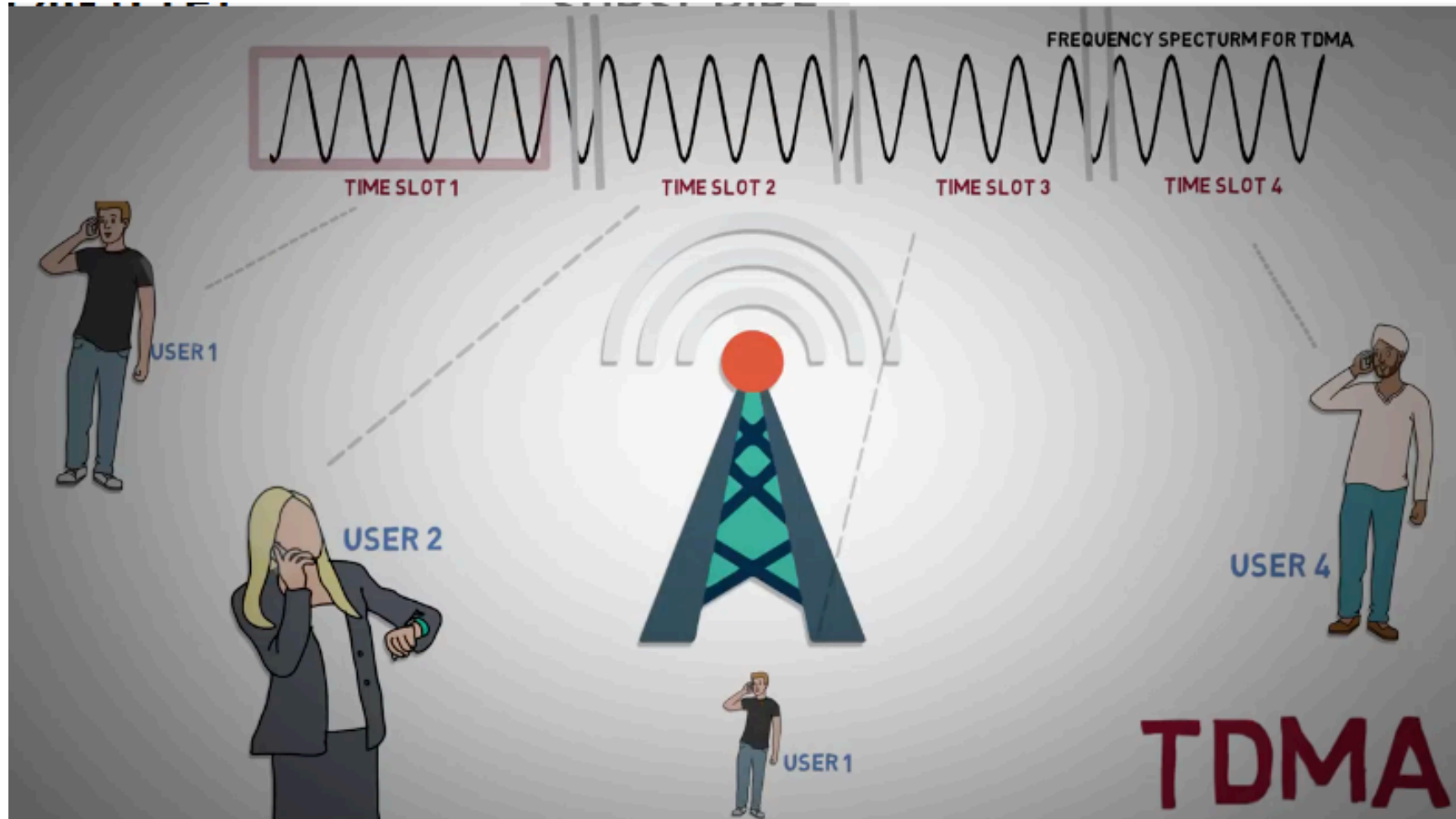


FDMA

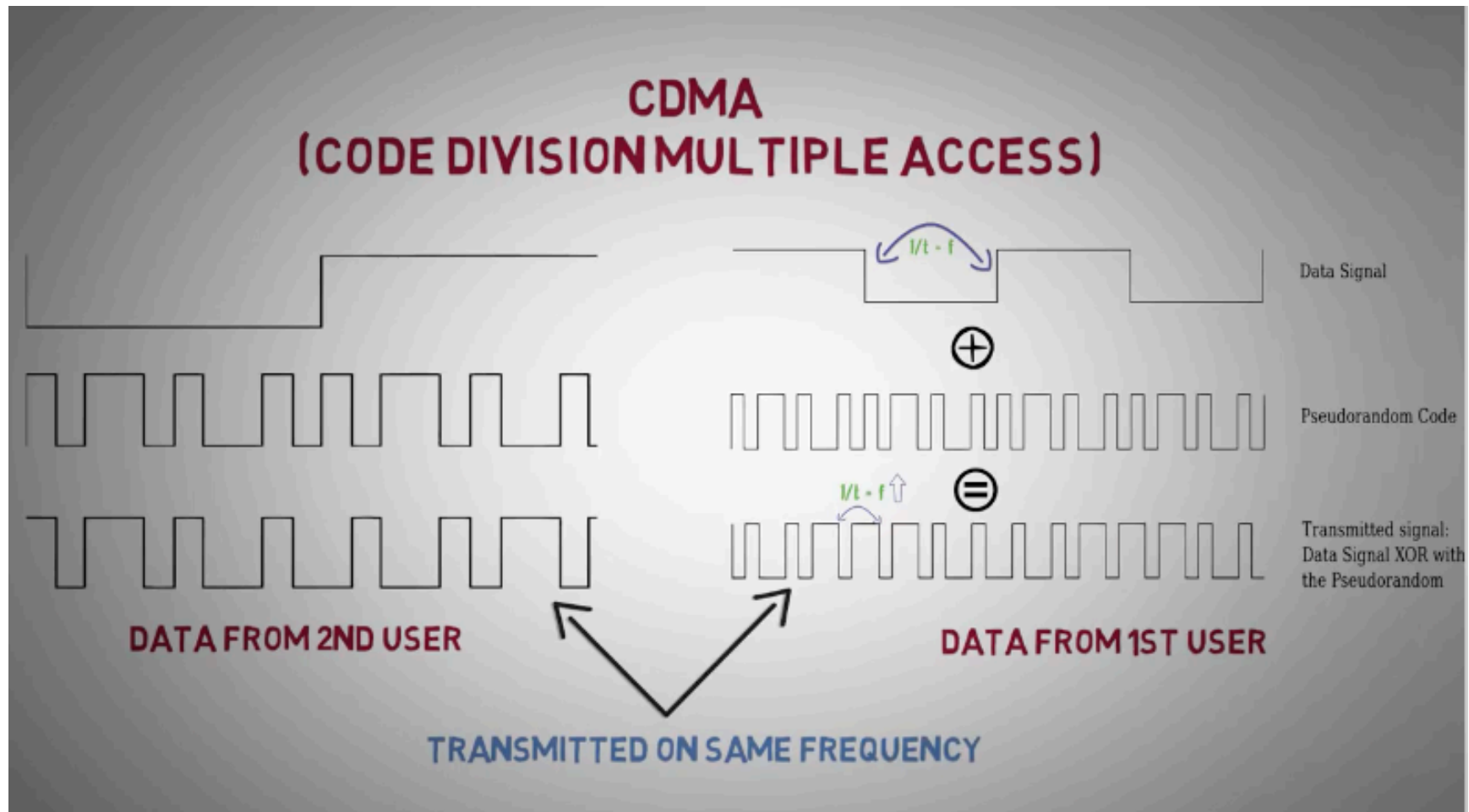




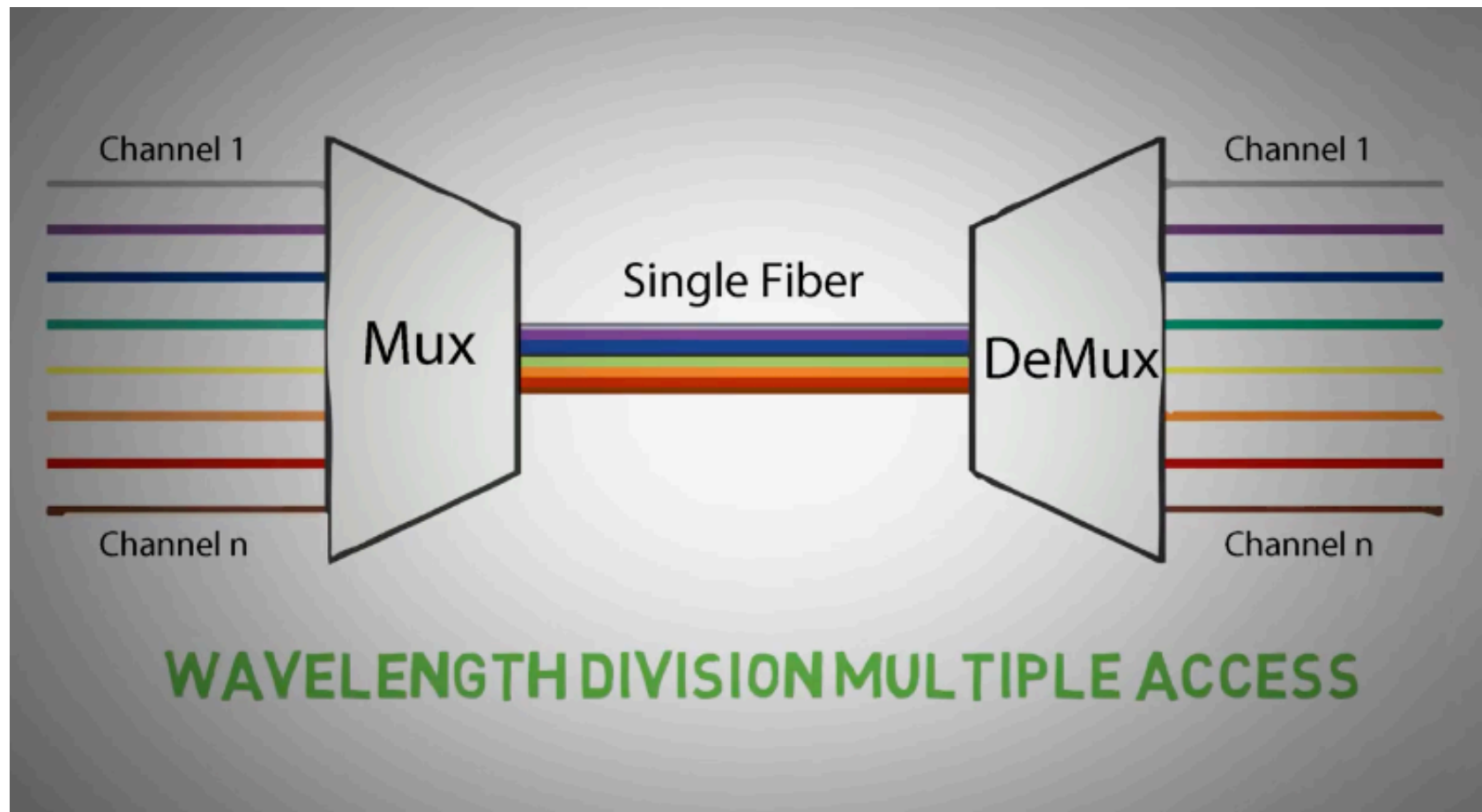
TDMA



CDMA

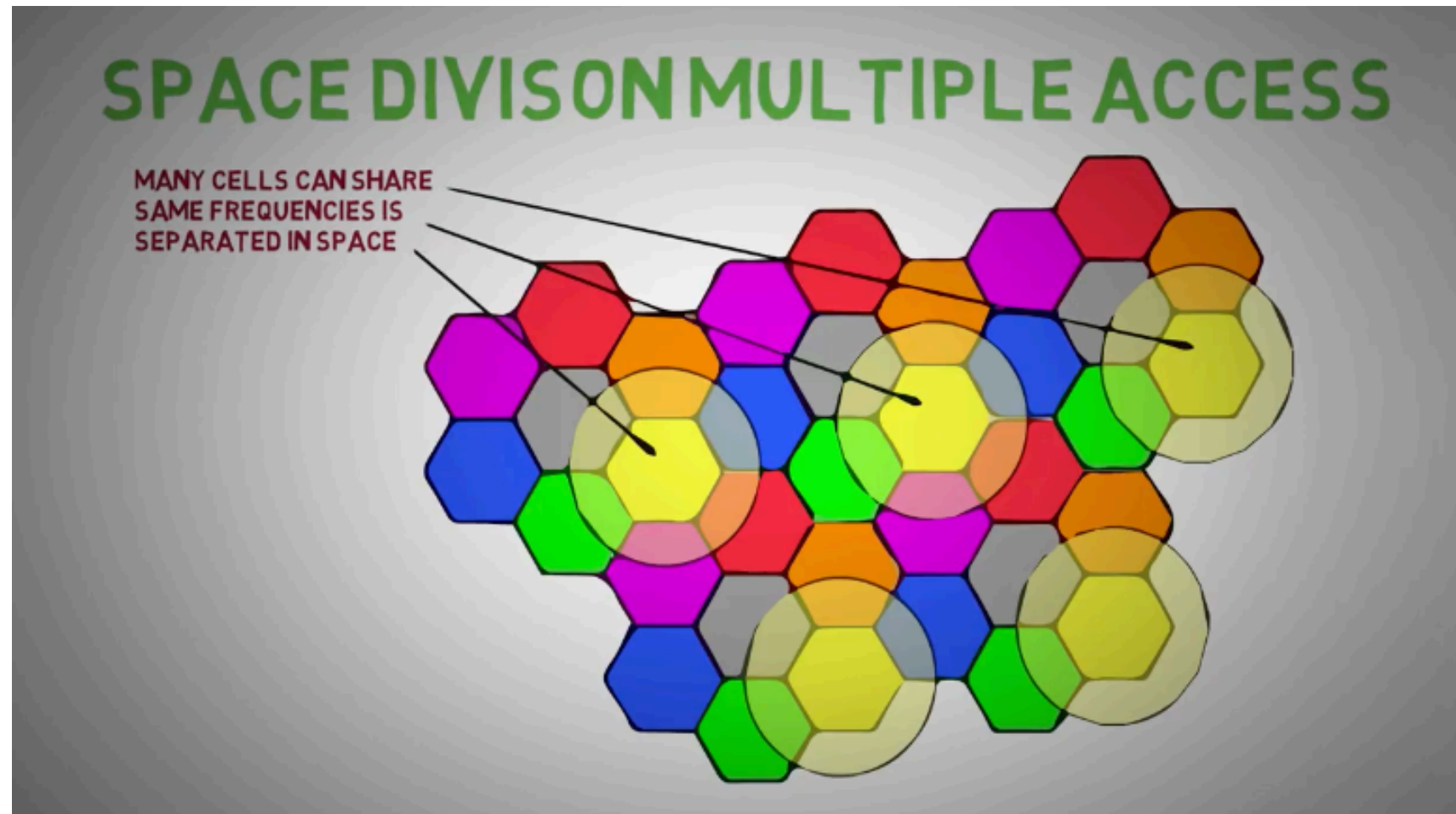


WDMA

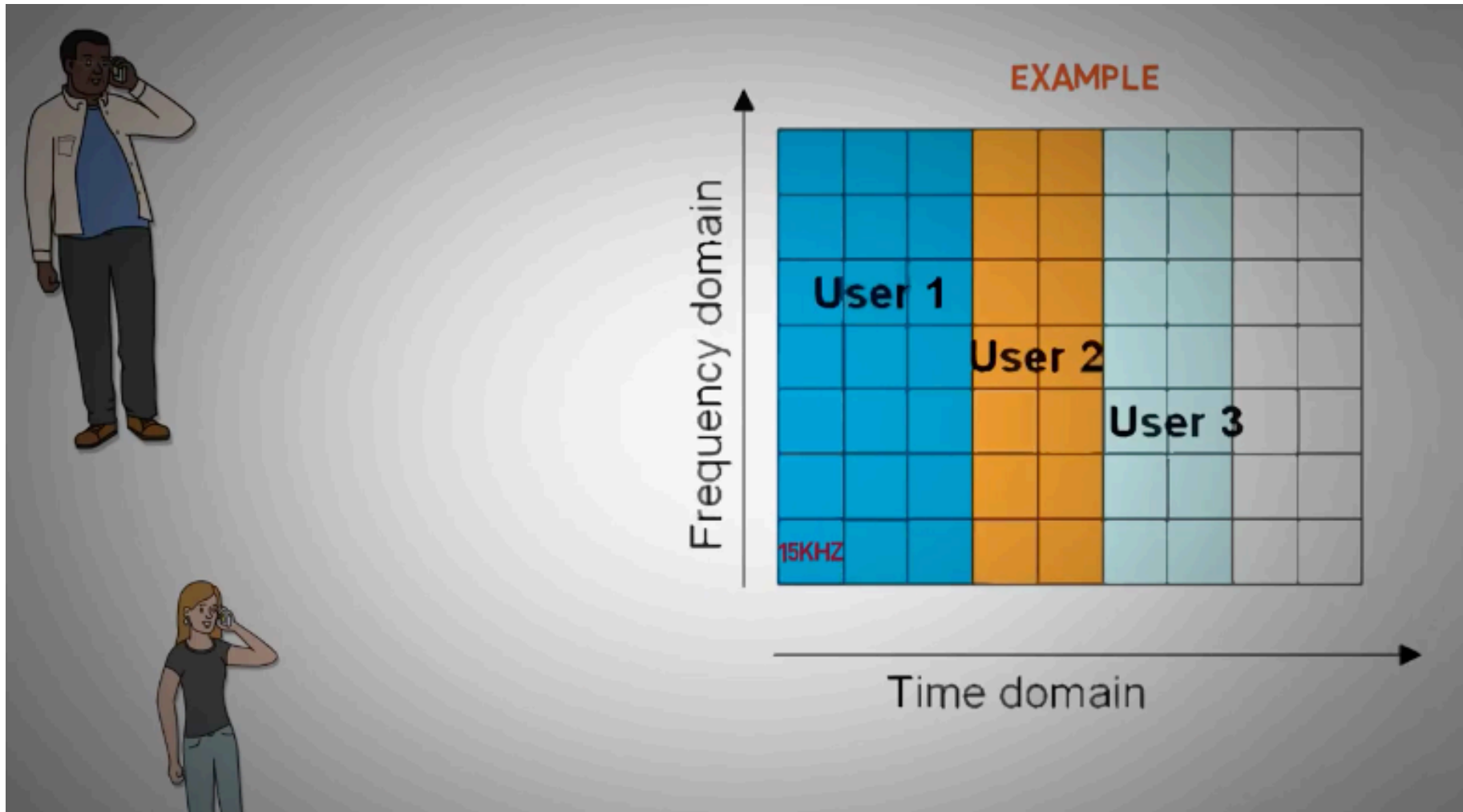




SDMA



OFDMA

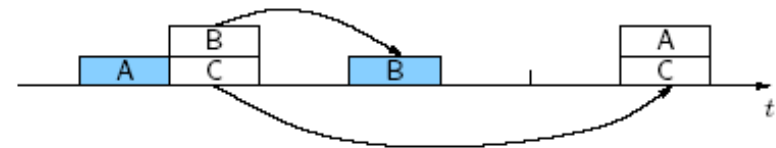
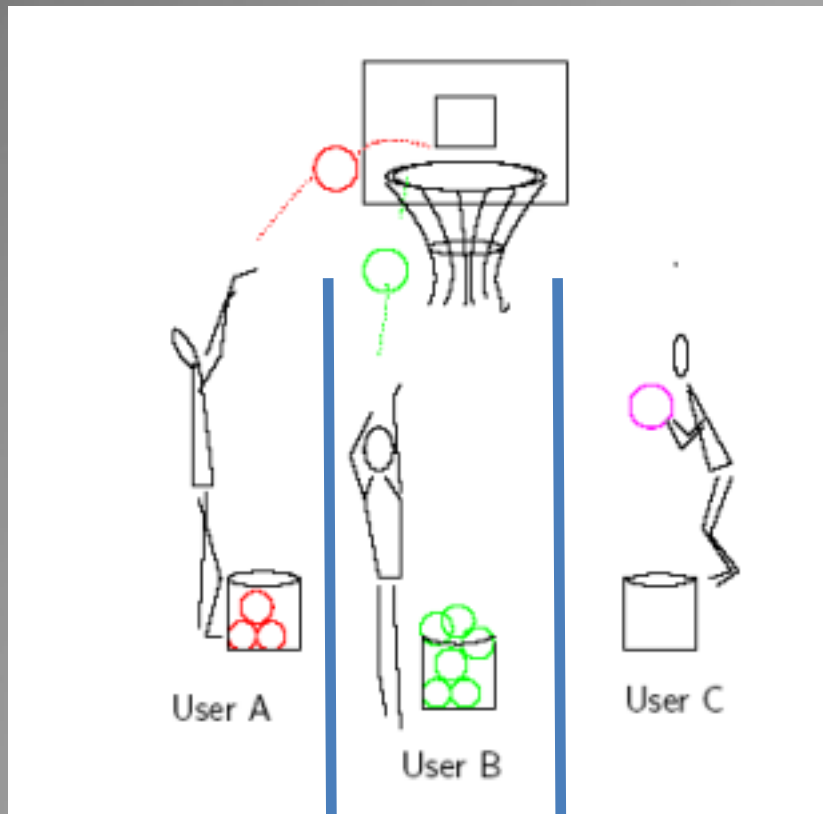




How does it work?

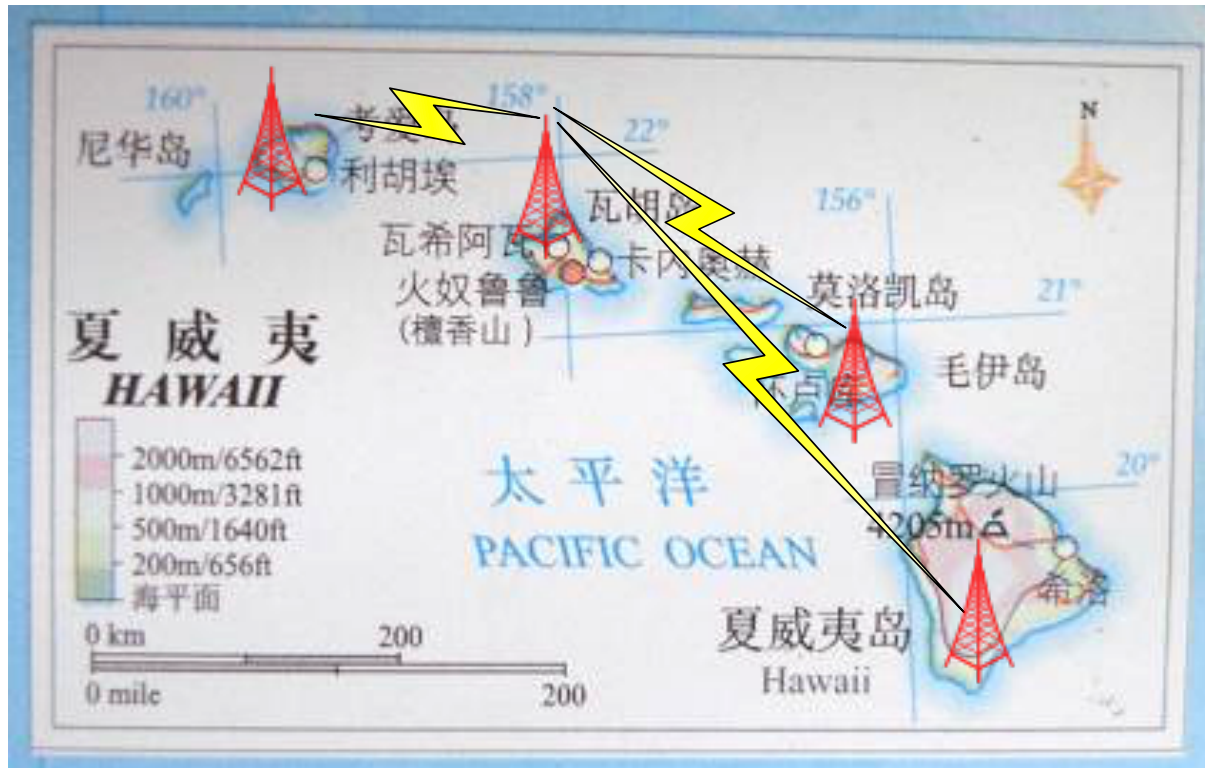


Random Access



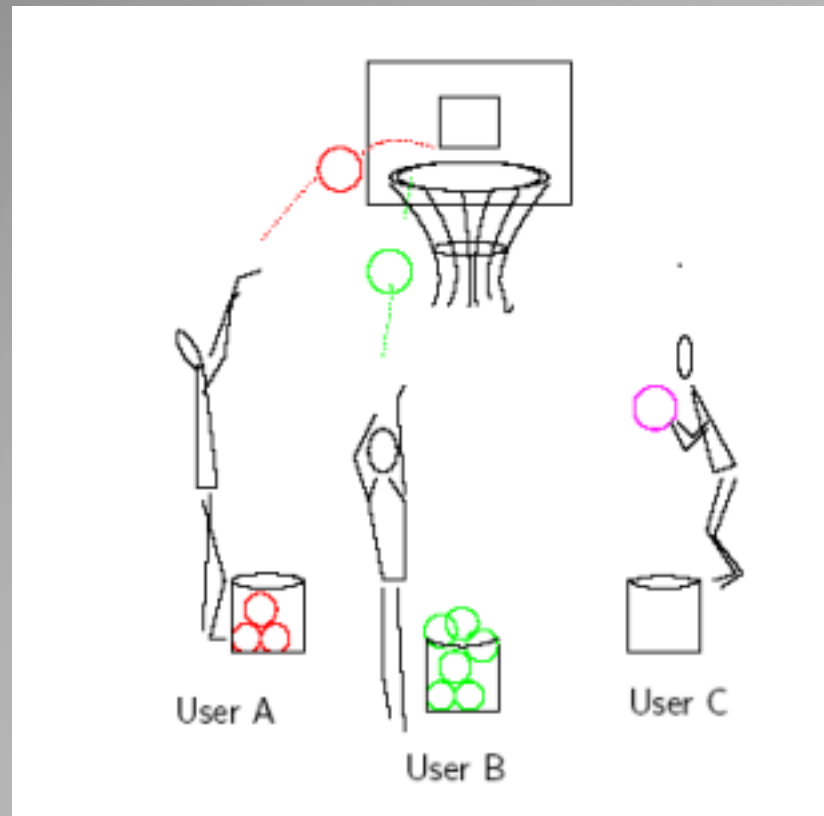


ALOHA





CSMA





Spectrum sharing between different systems

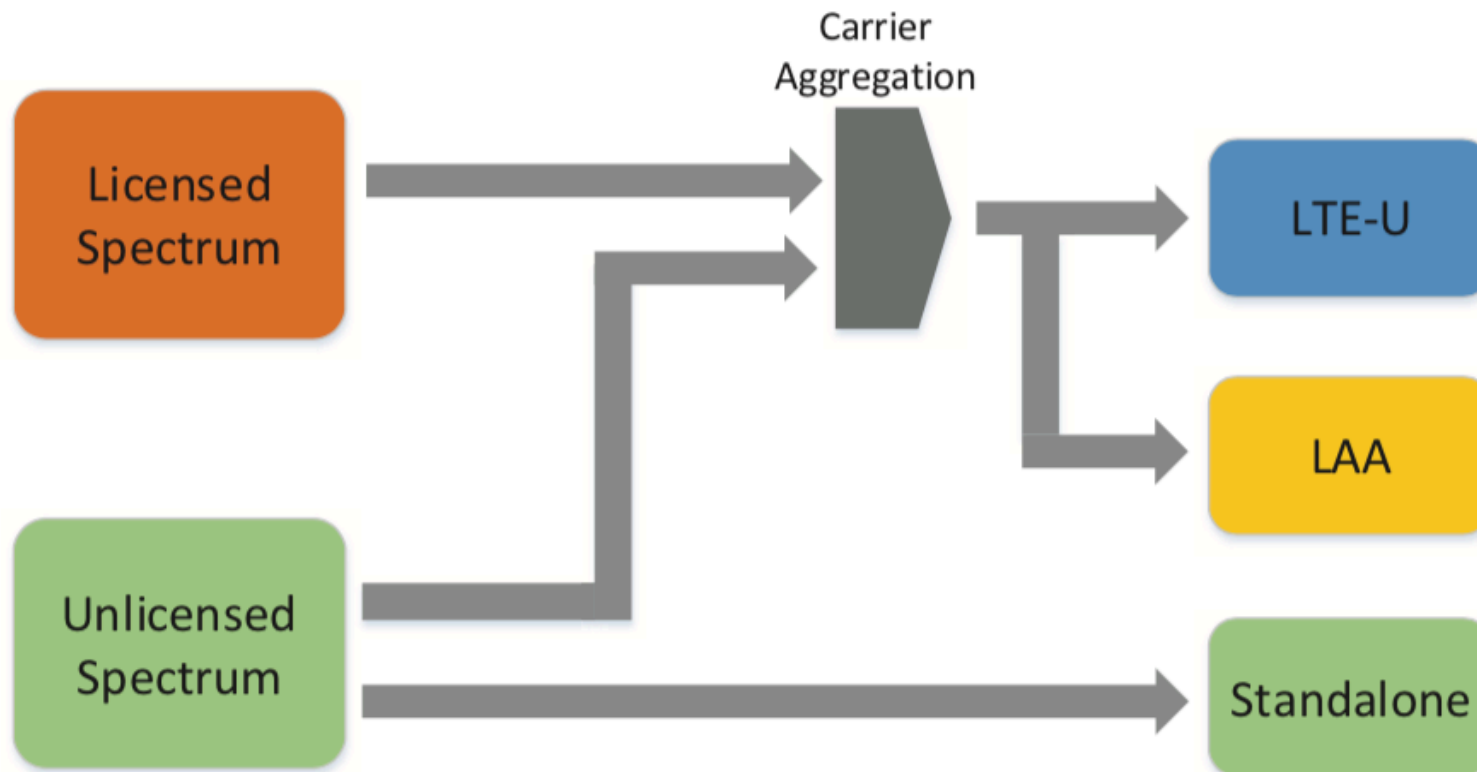
Cognitive Radio

- Spectrum sharing on **licensed** bands



LTE-U

- Spectrum sharing on **unlicensed** bands





LTE-U

LTE

WIFI

DEMAND IS SEEMINGLY INFINITE

WIRELESS SPECTRUM IS LIMITED

Future Direction

- **Spectrum sharing between a pair of users**
 - Full duplex at the same time and the same frequency

- **Spectrum sharing between multiple users**
 - Non-orthogonal multiple access

- **Spectrum sharing between different systems**
 - How does LTE-U coexist with Wi-Fi