Data: The frontier beyond Dynamic Spectrum

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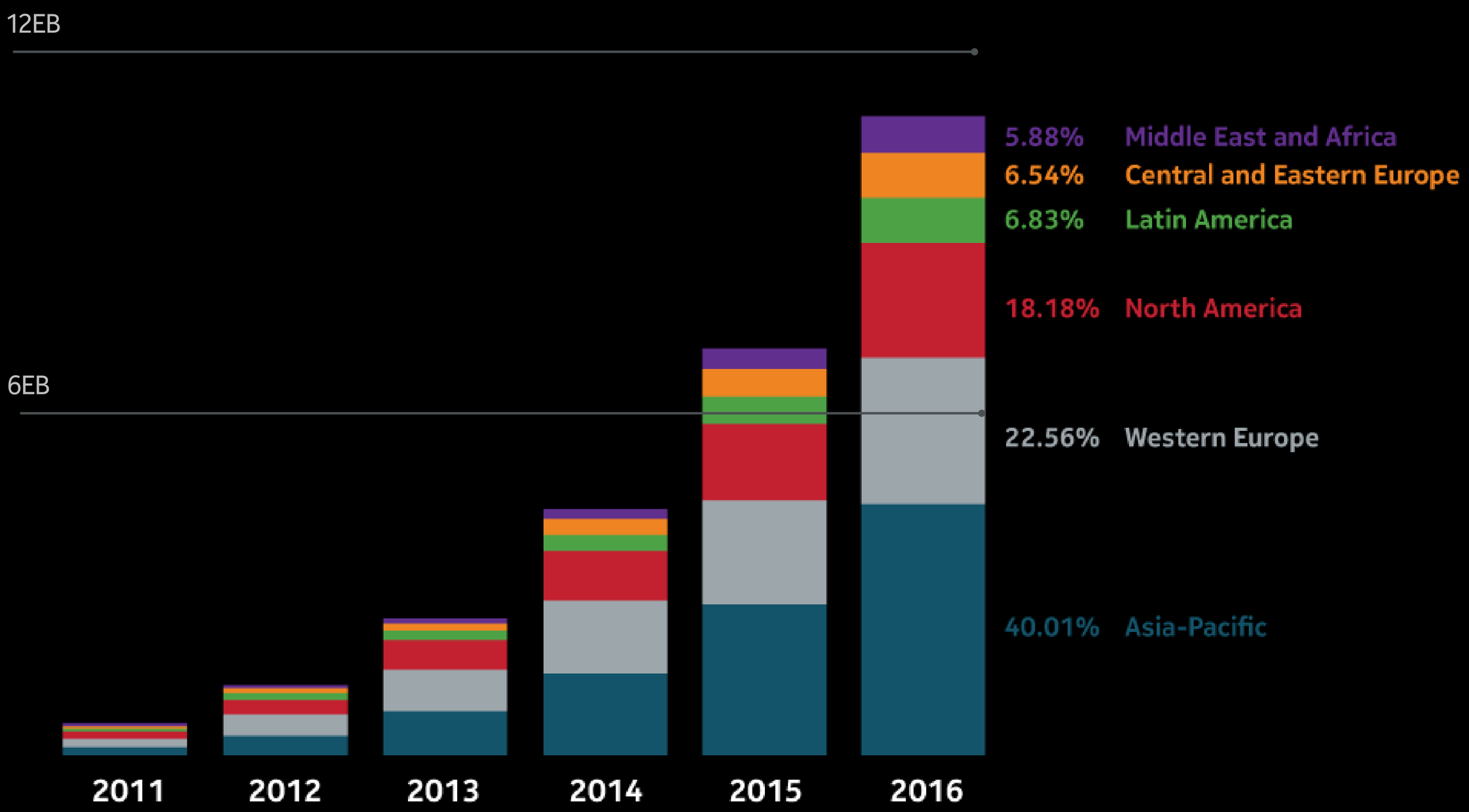
1 Capacity

2 Spectrum sensing as a sensor data source

Capacity: The rise of mobile data



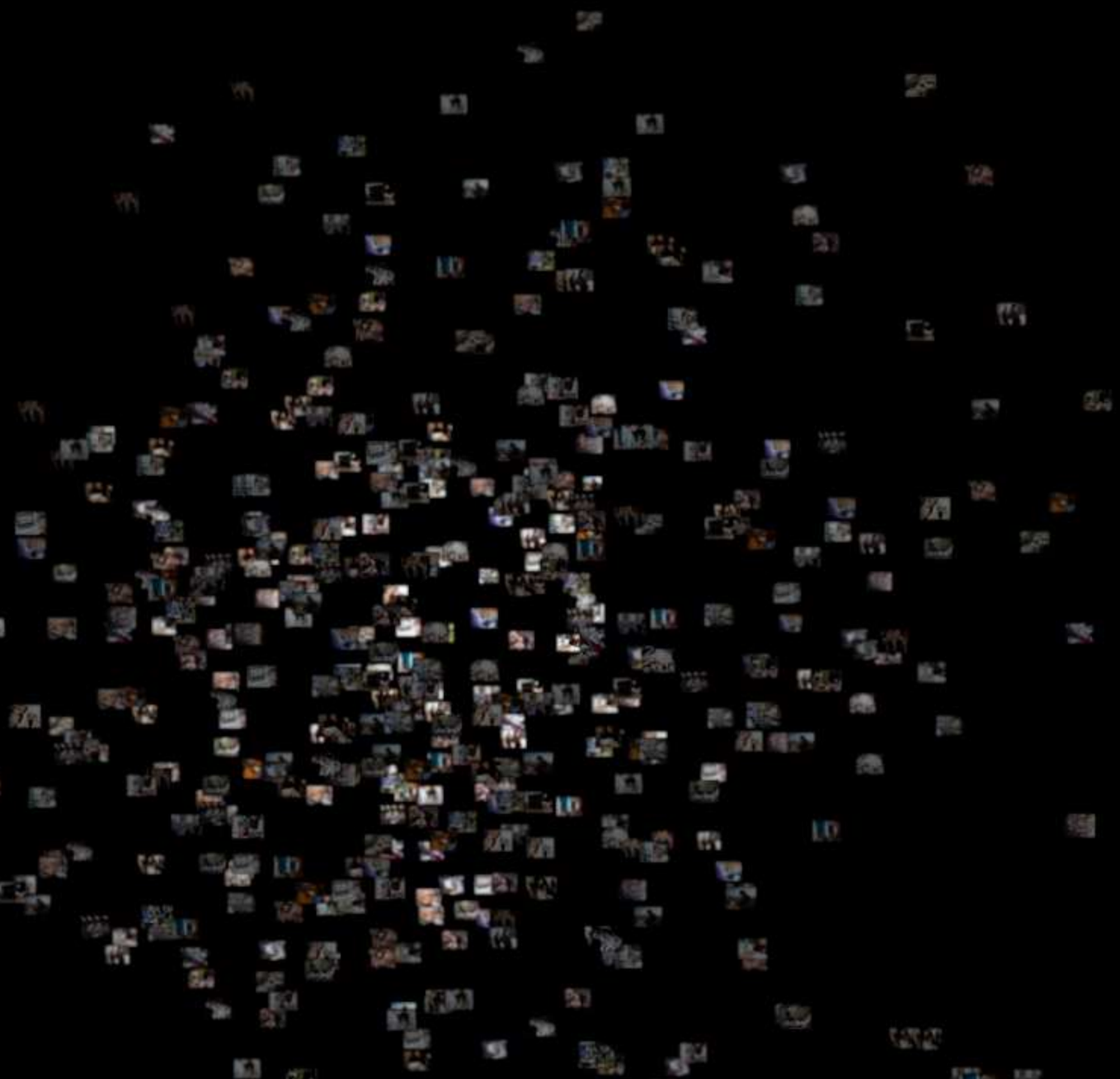
Source: Cisco VNI Mobile 2012

Bits eat Atoms.

Inside CERN- bits index Physics (Particle events).

906M

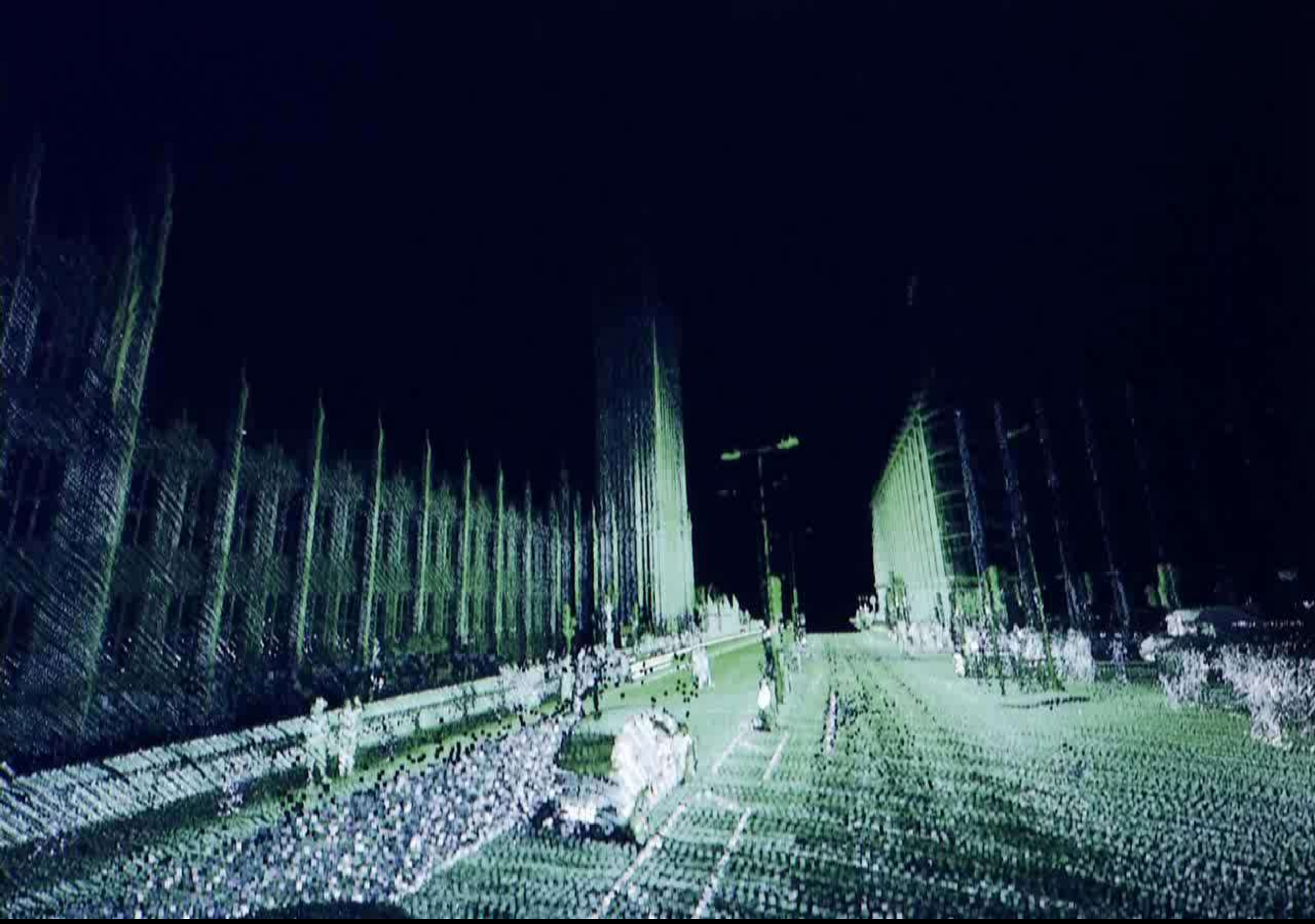
Social Media Users



Inside Facebook - bits index

Who (social networks).


Inside Nokia L&C - bits index
Where (navigation & location).




Why would Bits not index
Spectrum ?.

1 Index

2 Analytics

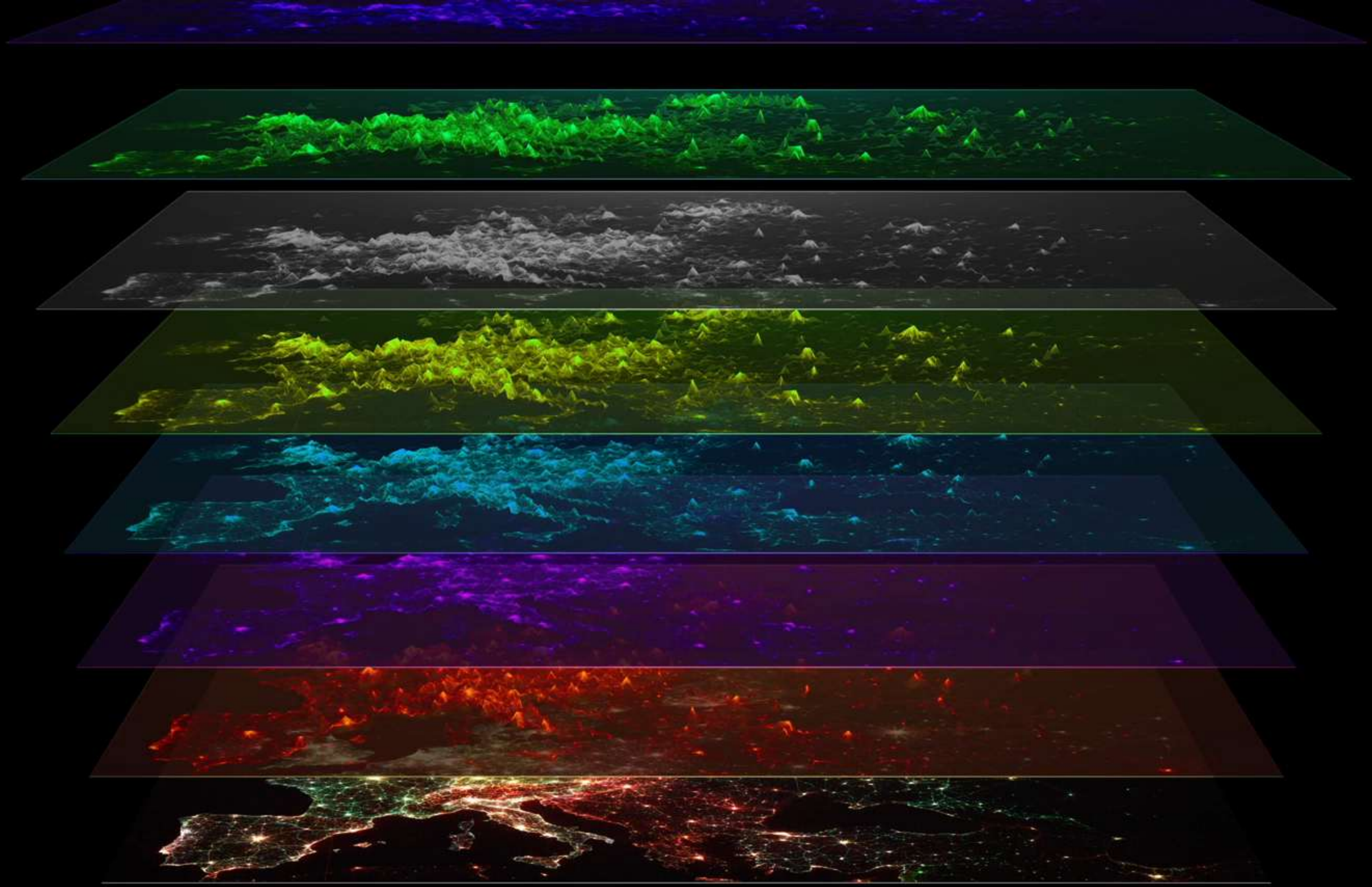
3 Business

“Money is made from information difference”.

Henry’s adaptation from Fortune’s Formula by William Poundstone

Sensors (& antennas) in smartphones today

- Gyroscope, inside camera module
- Proximity sensor, ambient light sensor
- Magnetometer
- Accelerometer
- Microphones
- Main cellular antennas
- Cellular diversity antennas
- CWS antennas (Bluetooth, WLAN)
- GPS antenna
- Wireless charging coil
- NFC coil



1Zettabyte ≈

Sextillion (10^{21})

Radio sensing in handsets 2012.

GSM 850, 900, 1800, 1900

WCDMA 850, 1800, 1900

LTE 1700/2100, 700

GPS

WiFi

Bluetooth 4.0

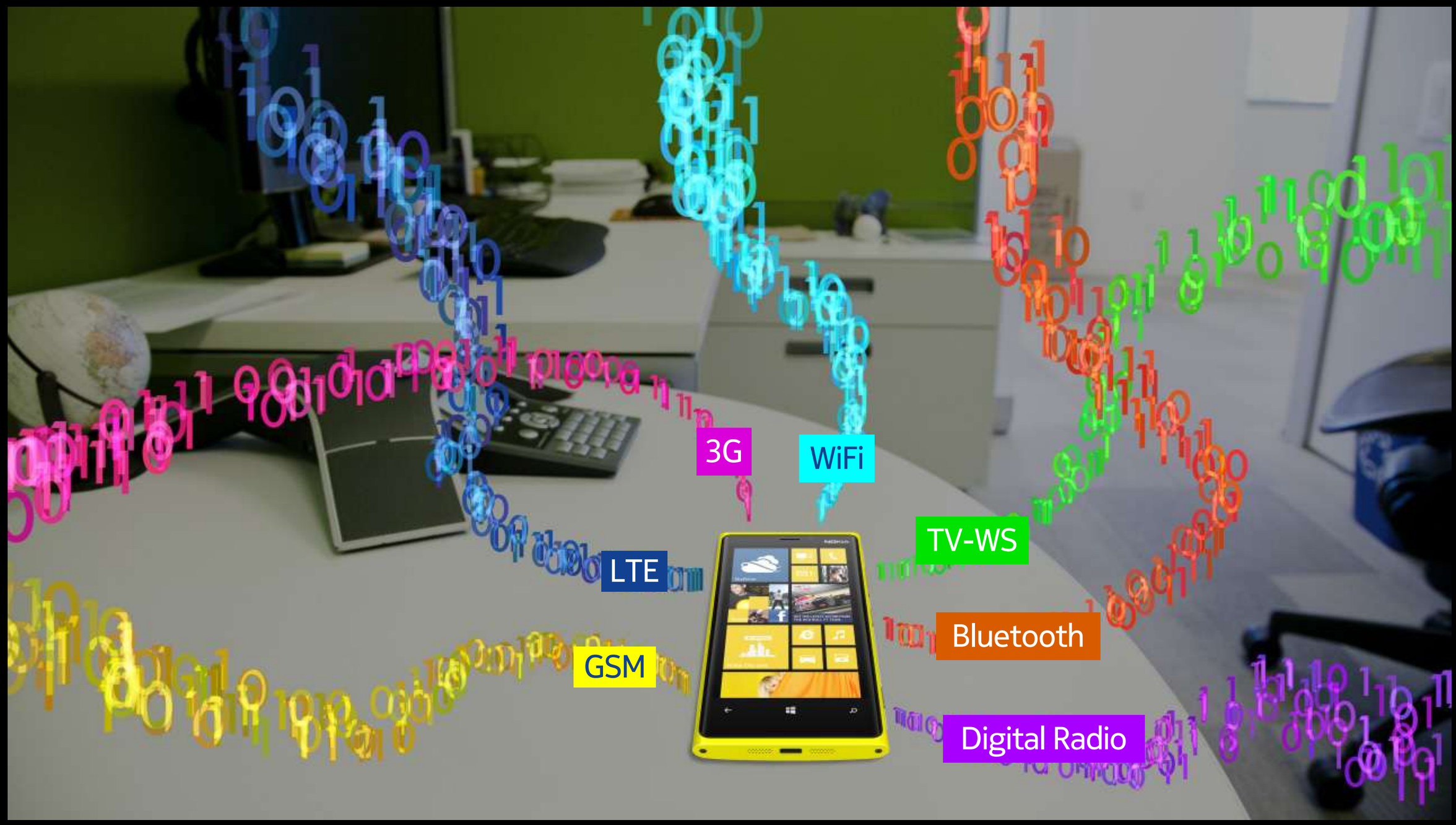
NFC

Wireless Charging

Radio sensing in the dynamic world.

CR Database 2

CR Database 1



Example:
Utilizing the CR data

CR Database

Location

Device Type

Device ID

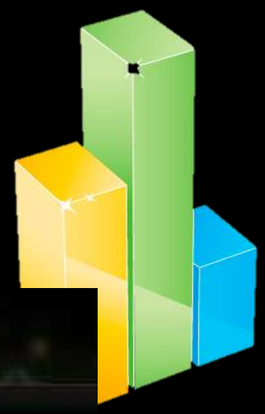
Frequency List

Permissions

Subscriptions

- Location Based Advertising
- Opt-in advertising
- Location driven access
- Demographics
- Routing to spectrum
- Service priority

- Segmentation
- Content form ty
- (Multi-screen) Usag
  pricing
-



Device/Session ID

CR Database

Spectrum information requests indexed by location.

(supervised and unsupervised) Density estimation in a grid in time and space (variants: granularity, non-iid)

What type of environments trigger spectrum queries

Associations of places in “spectrum sense”

Collaborative Filtering for recommendations based on spectrum behavior

Modeling considered to be difficult.

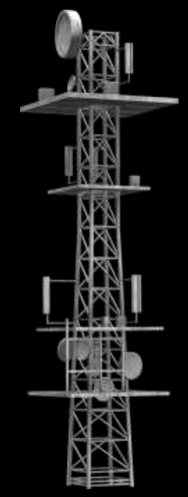
- Curse of dimensionality is real
  - Context data is high-dimensional
  - Even discrete (binary) vectors suffer from sparseness
- Scale often rules out lots of traditional algorithms (like standard O(n^2) SVMs, brute force k-means, …).
- “Too much data” – the model (family) is too simple



Negotiauctions

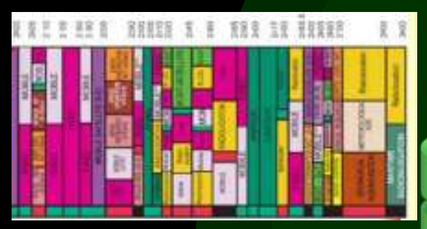
Radio environment (measured)

Operator B



Operator A

Spectrum map (planned)



CR Database 1

Subscriptions and offers

Subscriptions and offers

CR Database 2

Federal Spectrum

Radio environment (measured)

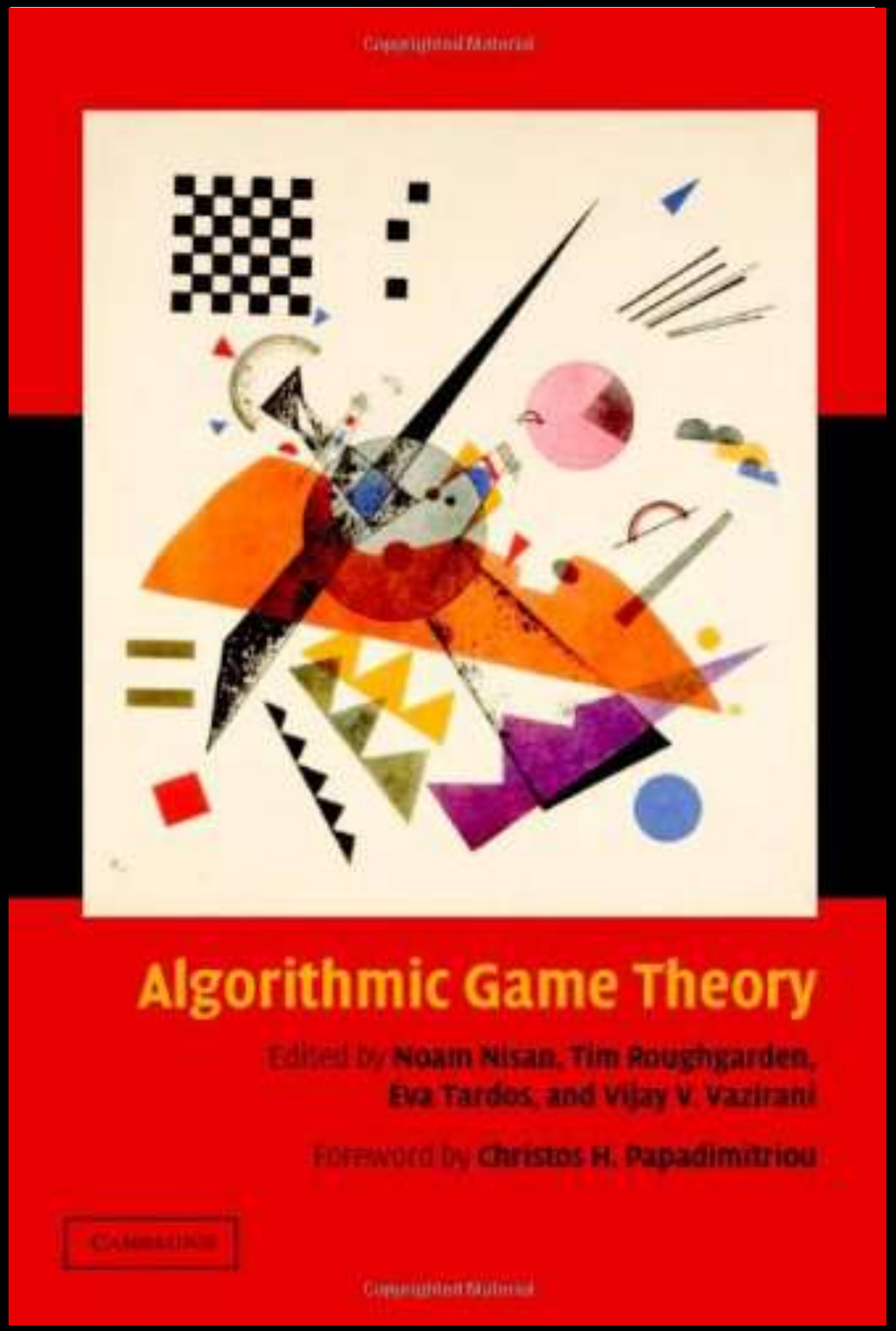
TV - WS

NEW DEALMAKING STRATEGIES FOR
A COMPETITIVE MARKETPLACE

NEGOTIAUCTIONS

"Packed with transformative insights, Negotiauctions will help a new generation of business leaders get to yes."
—**WILLIAM URY**, coauthor of Getting to Yes and author of *The Power of a Positive No*

GUHAN
SUBRAMANIAN



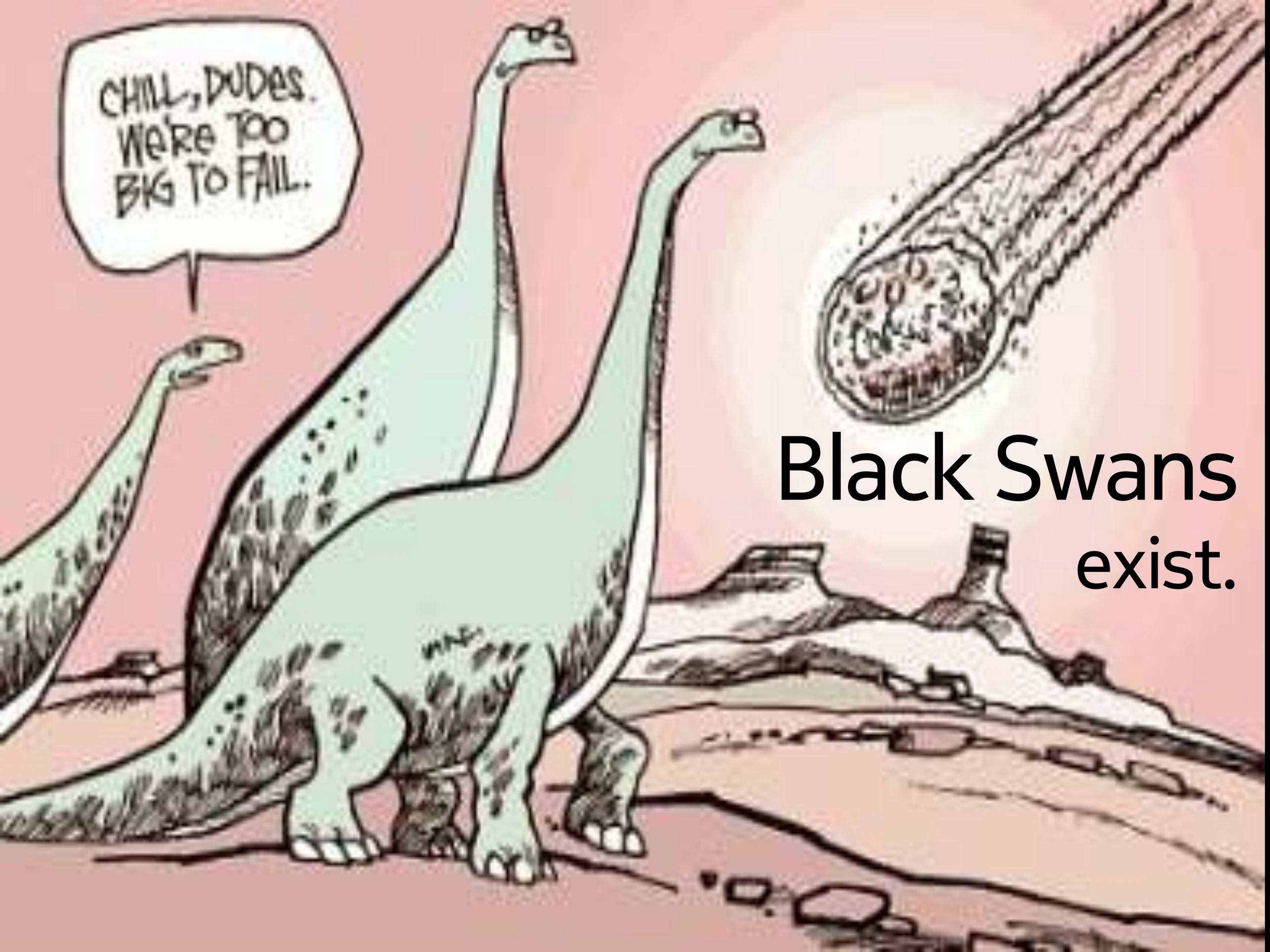
“Bits” approach needs algorithmic Game Theory

- Nisan, Noam; Ronen, Amir (1999), "Algorithmic mechanism design", Proceedings of the 31st ACM Symposium on Theory of Computing (STOC '99), pp. 129–140, doi:10.1145/301250.301287

1. With what other data spectrum sensing data should be combined with?

2. Analytics for spectrum sensing – Déjà vu or novelty?

3. Energy implications?


CHILL, DUDES. WE'RE TOO BIG TO FAIL.
Black Swans exist.