# TV White Space Based Super Wi-Fi

## — Opportunity for Hong Kong ?

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# Outline

Background

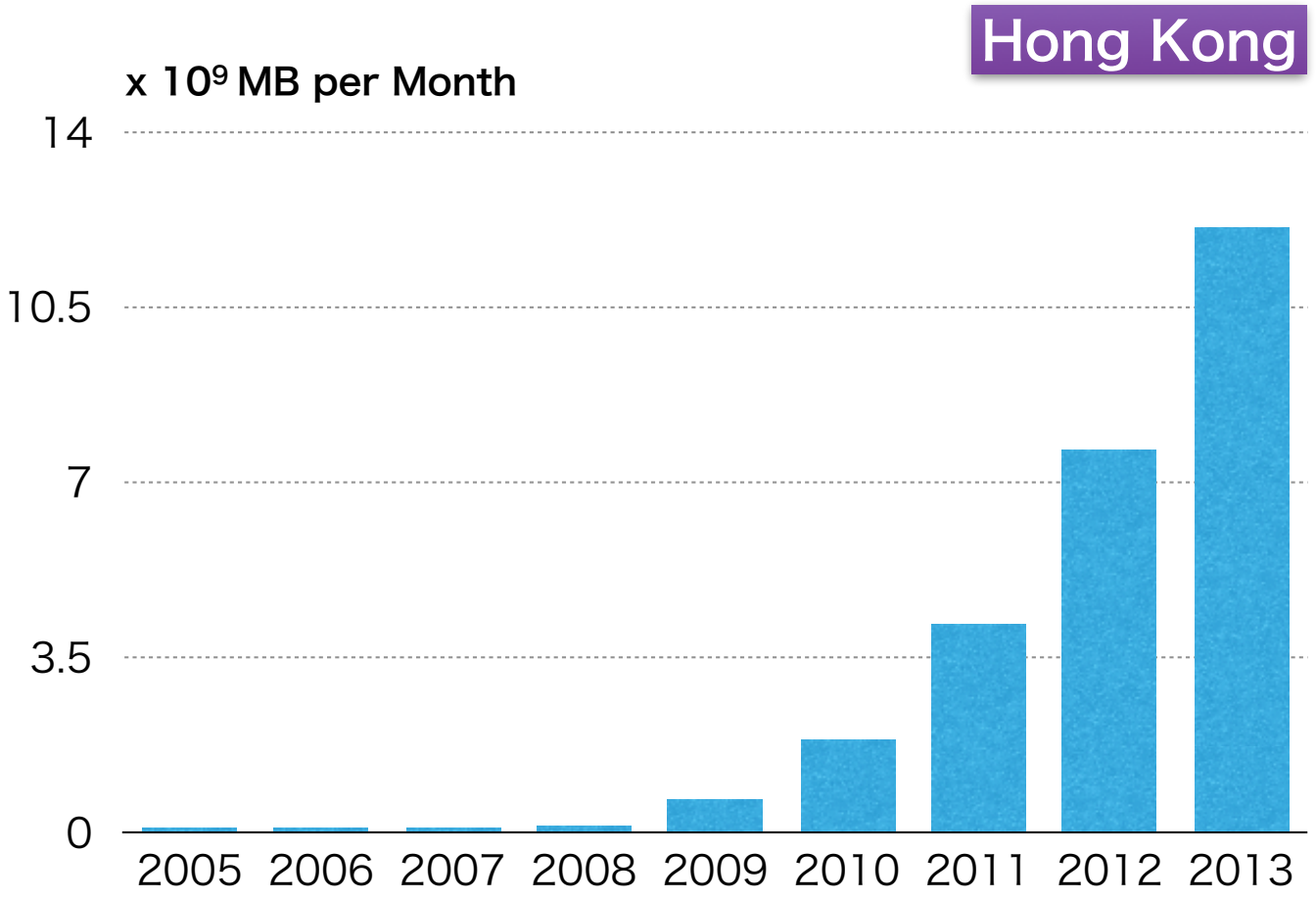
Current
R&D Status

Our Study

# Background

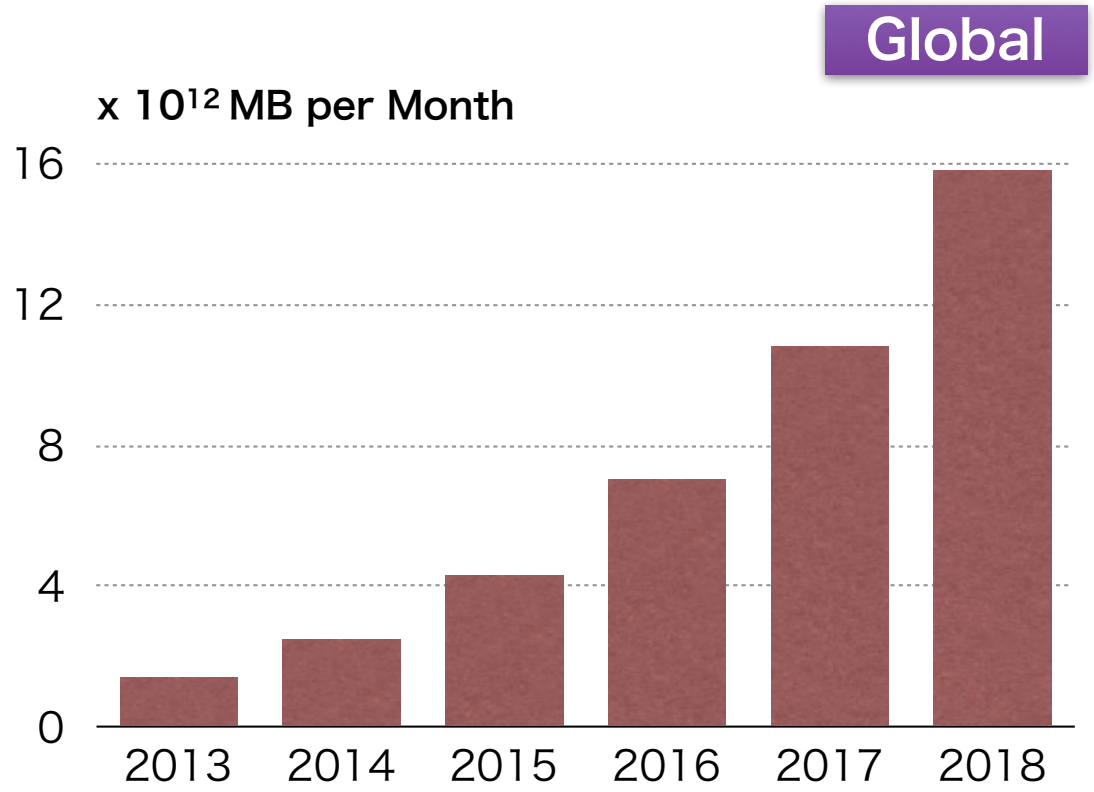
# Mobile Data Explosion

- Hong Kong Mobile Data Traffic, 2005 to 2013 (from OFCA)



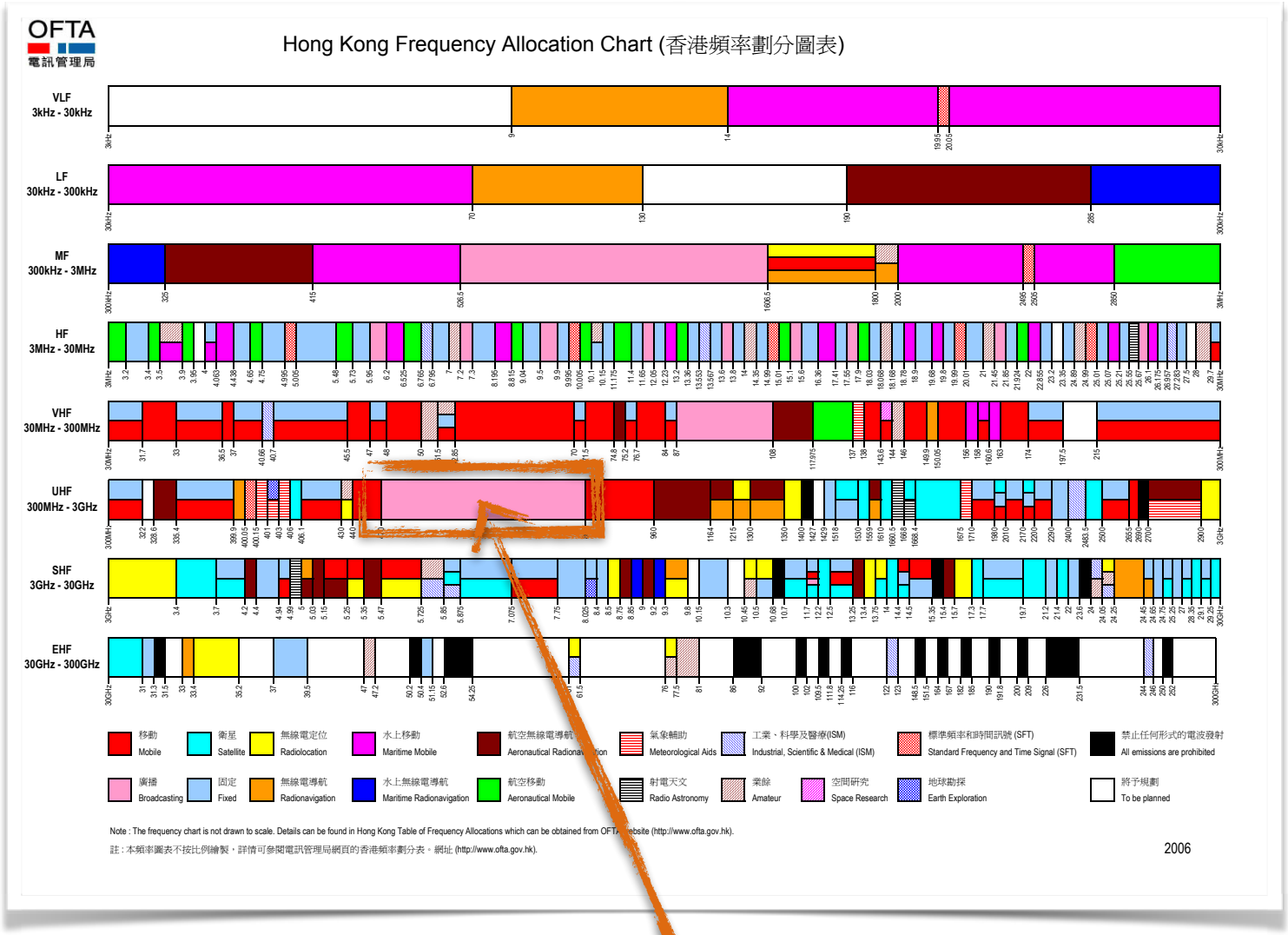
# Mobile Data Explosion

- Global Mobile Data Traffic Forecast, 2013 to 2018 (from Cisco)



The mobile data traffic explosion calls for more radio frequency resource for wireless broadband services.

# Frequency Allocation in HK




TV Band (470~806 MHz)

# TV White Spaces

- TV White Spaces refer to the vacant (unused) frequency channels in the TV band.

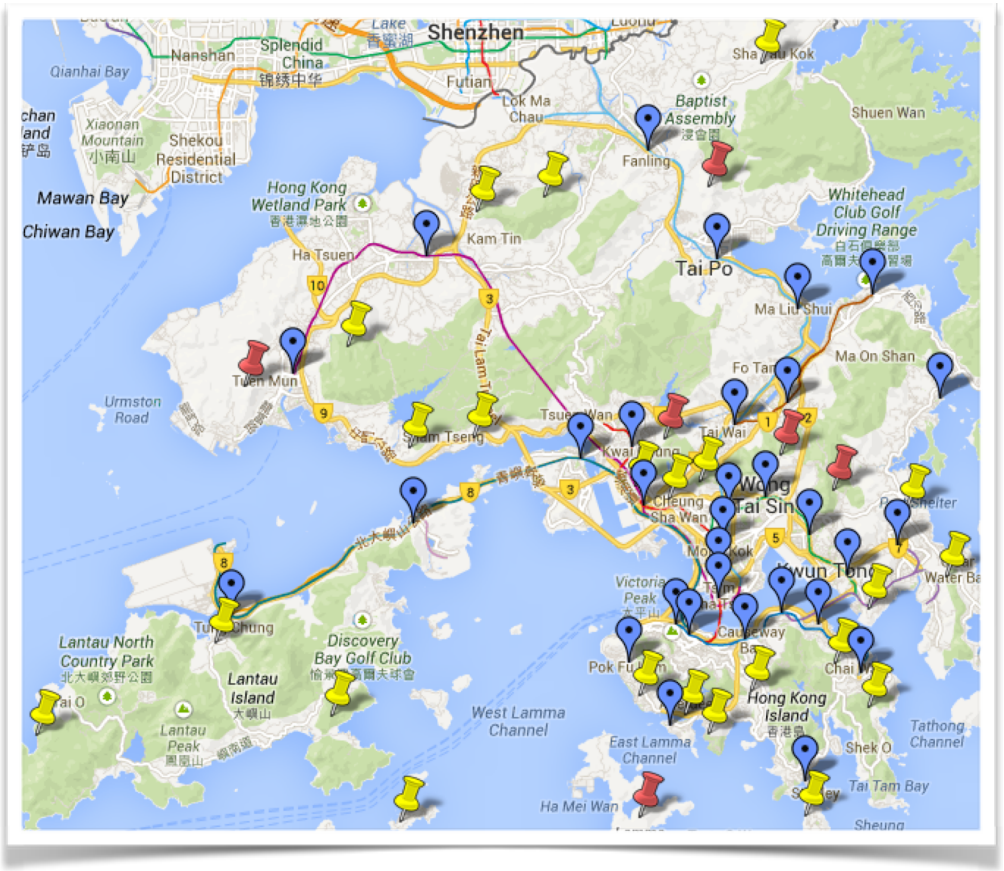
- A Trend: Explore TV White Spaces
  - Excellent Propagation Characteristics
  - Low TV Band Utilization by Incumbent TV Broadcasters

# TV White Spaces in HK

- TV Band in HK: 470 ~ 806 MHz
  - 42 frequency channels (8 MHz bandwidth per channel)
- Two major TV broadcasters: ATV and TVB
  - ATV: 2 analogue TV channels and 6 DTT channels
  - TVB: 2 analogue TV channels and 5 DTT channels

# TV White Space Usage in HK

- A Large-Scale Measurement Study in Hong Kong [1]
  - 6 Principle Stations, 23 Fill-in Stations
  - 31 Measurement Locations




Principle TV Station
Fill-in TV Station
Measurement Location

# TV White Space Usage in HK

- A Large-Scale Measurement Study in Hong Kong [1]
  - Average Outdoor White Space Ratio: 50% (170MHz)
  - Average Indoor White Space Ratio: 70% (240MHz)

| | Outdoor (Urban) | Outdoor (Suburban) | Outdoor (Rural) | Indoor (Urban) | Indoor (Suburban) | Indoor (Rural) |
|---|---|---|---|---|---|---|
| TV White Space Ratio (%) | 44.1 | 55.9 | 60.9 | 67.9 | 74.7 | 73.3 |
| Vacant Channel Number | 18.5 | 23.5 | 25.6 | 28.5 | 31.4 | 30.8 |
| Total Vacant Bandwidth | 148 | 188 | 204 | 228 | 251 | 246 |

# Global TV White Space Usage

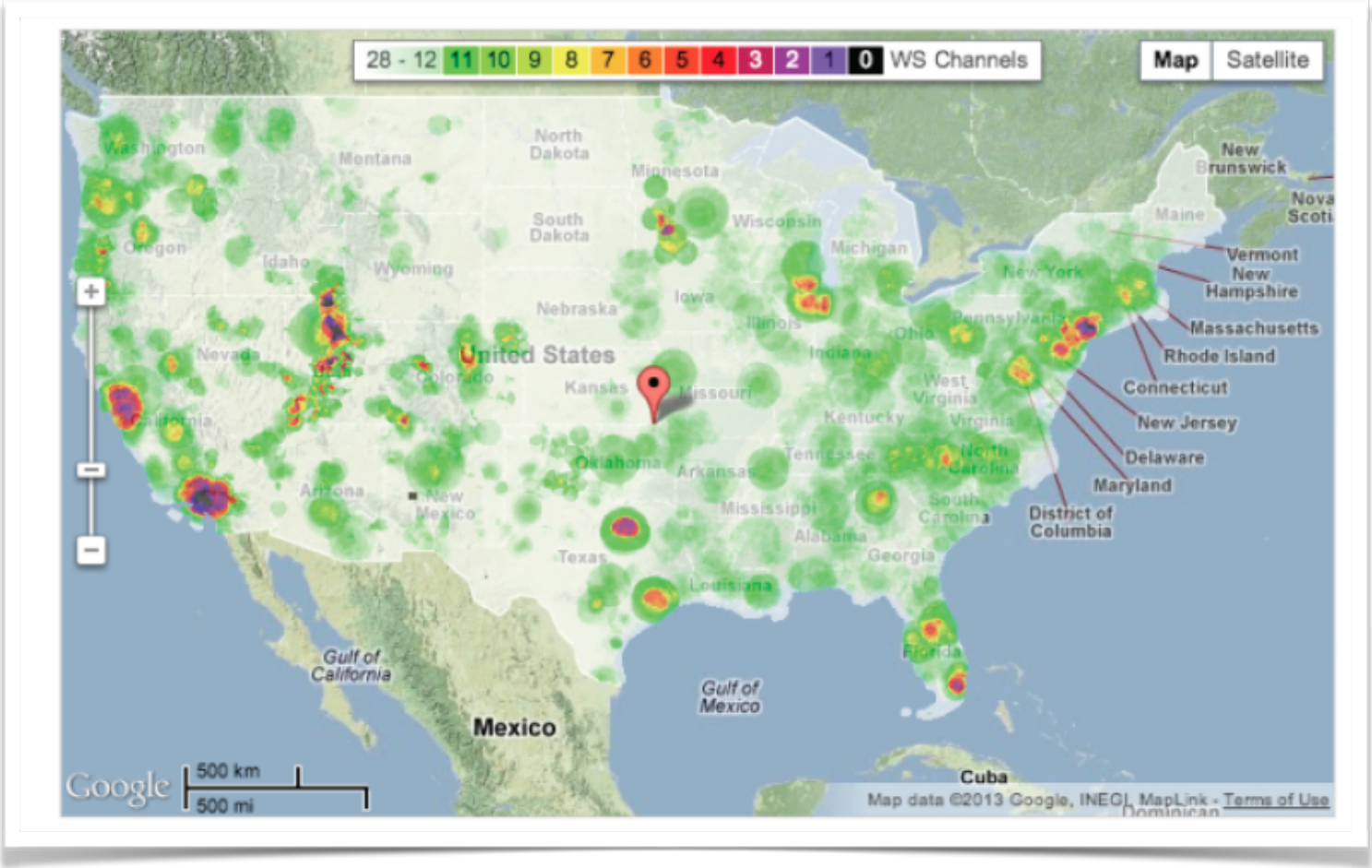
- A Survey of TV White Space Measurements [2]
  - More than 100MHz TV white spaces in most counties (urban)

Table 1. Total white spaces found by different studies in MHz

| | | No guard bands | | | Guard bands | | |
|---|---|---|---|---|---|---|---|
| Type | Location | Urban | Urban Indoor | Rural | Urban | Rural | Year Published |
| 1. Database | UK | ≈150 | | | ≈30 | | 2009 [13] |
| 2. Database | Europe | 176 | | | | | 2011 [15] |
| 3. Database | Europe | ≈125 | | | 30 | | 2012 [9] |
| 4. Database | India | ≈112 | | | | | 2014 [12] |
| 5. Detector | India | 194 | | 217 | | | 2013 [7] |
| 6. Detector | China | 168 | | 32 | | | 2012 [17] |
| 7. Detector | China | ≈232 | | | | | 2013 [16] |
| 8. Detector | Hong Kong | ≈168 | ≈235 | | | | 2013 [18] |
| 9. Detector | Philippines | 304 | | | | | 2012 [14] |
| 10. Detector | South Africa | ≈307 | | | | | 2013 [2] |
| 11. Detector | Uganda | ≈208 | | | | | 2013 [6] |
| 12. Detector | Vietnam | ≈141 | | | | | 2011 [1] |
| 13. Detector | Italy | 48 | 304 | | | | 2014 [3] |
| 14. Detector | Romania | 168 | | 262 | | | 2014 [10] |

# TV White Space Map in USA

- TV White Space Channels in USA (From Google)
  - More than 10 TV white space channels in most places



How to effectively and efficiently use these TV white space channels?

→ Super WiFi

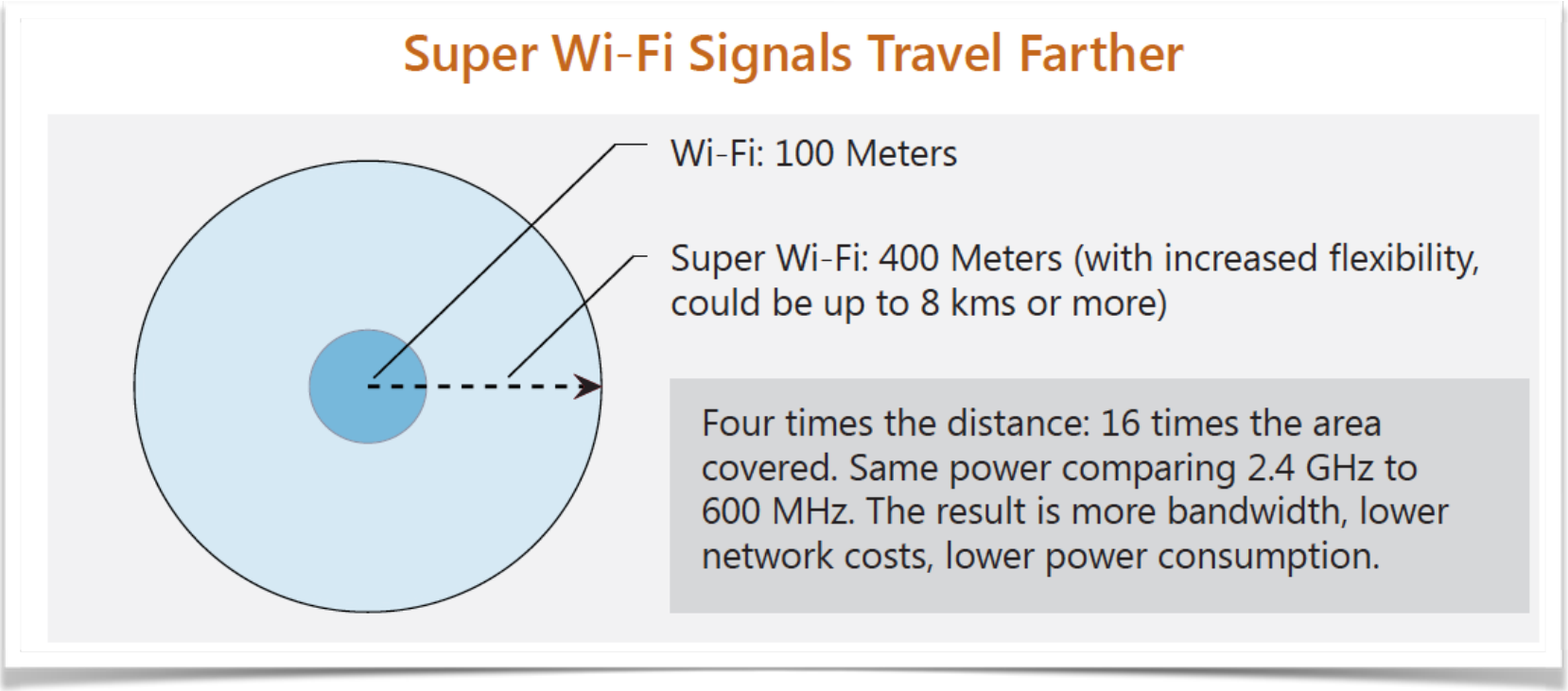
# What is Super Wi-Fi ?

- Super Wi-Fi refers to a new type of license-exempt (unlicensed) radio access technology that operates on TV white spaces.

- Super Wi-Fi is much more powerful than conventional Wi-Fi (operated on 2.4G or 5G radio frequency).
  - Large Transmission Distance
  - Obstacle Penetration / Avoidance

# Benefits From TV White Spaces

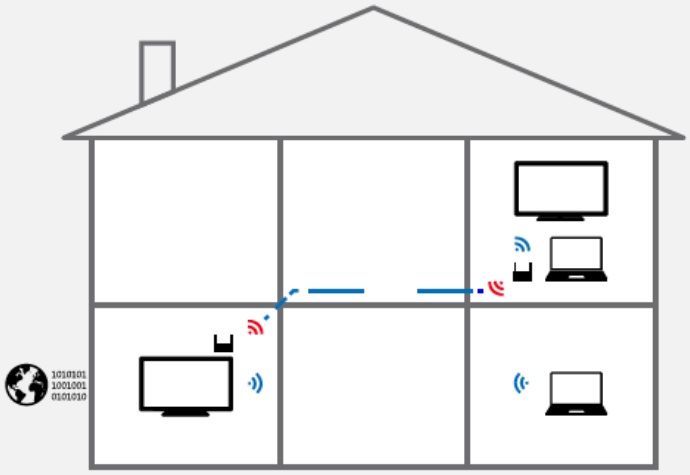
- Large Transmission Distance
  - 100m vs 400m or larger



# Benefits From TV White Spaces

- Obstacle Penetration / Avoidance
  - Penetrate 2 walls vs more than 2 walls

## Super Wi-Fi Signals Penetrate More Walls



- In a typical home, a Wi-Fi signal can penetrate up to two walls. At the same time, a TV white spaces signal can penetrate through more walls and obstacles,enabling whole home media distribution.
- This will simplify and enrich in-home/ in-building networking opportunities.

# How Super Wi-Fi Works ?

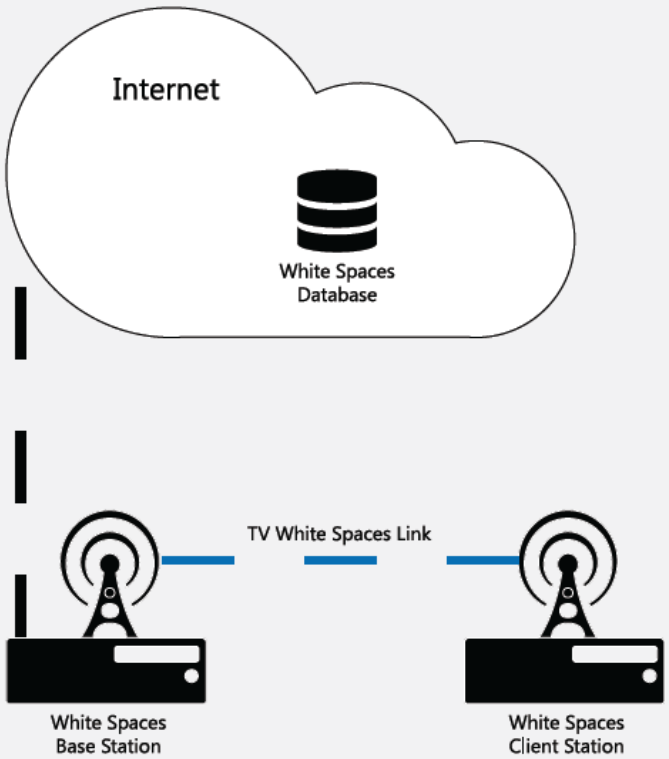
- Key Requirement: Reliably detect the available TV White Spaces, so as to avoid causing interference to incumbent devices of TV broadcasters and receivers.

- Approach: Geo-location White Space Database

# How Super Wi-Fi Works ?

- Approach: Geo-location White Space Database

## Super Wi-Fi Access Safeguards Incumbents from Interference




1. Devices only use the TV white spaces channels specified by the database.
2. Devices are required to re-check the database for the list of available channels.
3. Databases are prohibited from providing devices access to the channels occupied by incumbent operators (e.g. broadcasters).
4. Databases are required to maintain up-to-date lists of protected operators.
5. Databases can block newly occupied channels to prevent further white spaces access.

# Potential Use Cases

- Utilizing Large Transmission Distance:
  - Cellular Offloading
  - Rural Broadband / Backhaul
  - Wide-Coverage Hotspots
  - Bridge among Small Networks
  - Sensor Networks
  - Wireless Surveillance System

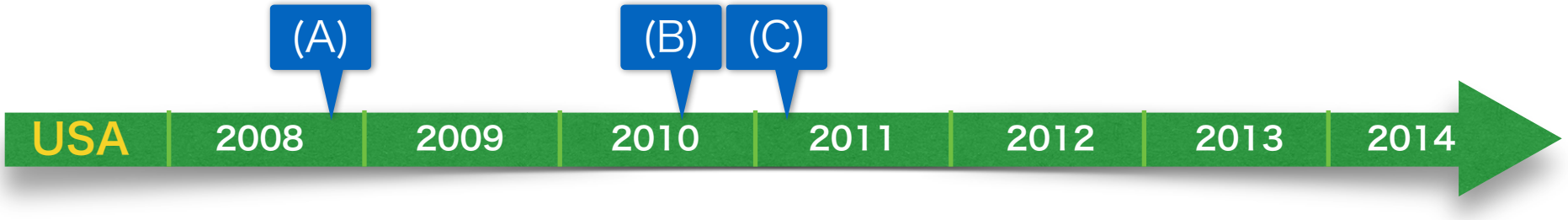
- Utilizing Obstacle Penetration / Avoidance
  - Indoor Video Distribution
  - M2M Communications — Factory Floor Automation
  - D2D Networks

# Current R&D Status

# Super Wi-Fi Trails & Demos

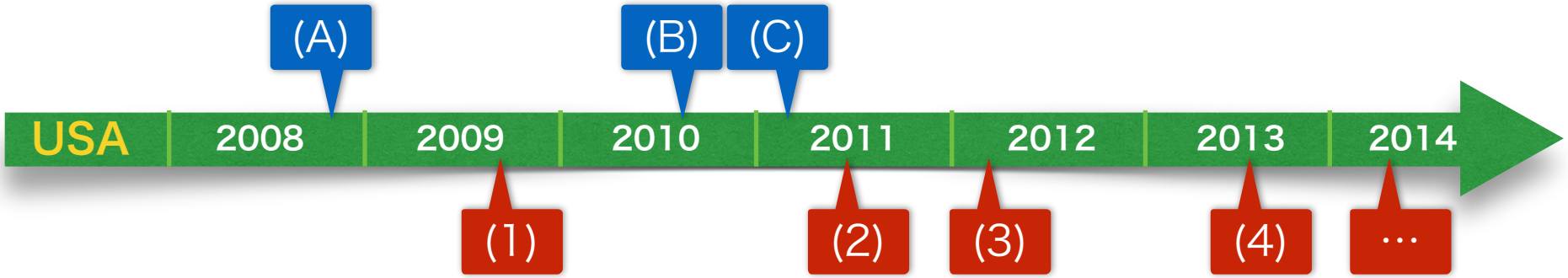
# Policy and Trails in USA

- Policy of FCC in USA
  - (A) Nov 2008, FCC approved the unlicensed use of TV white spaces;l
  - (B) Sep 2010, FCC determined the rules for the use of TV white space (using database, and removing sensing);
  - (C) Jan 2011, FCC conditionally designated 9 companies (including Google, Spectrum Bridge, Microsoft) to serve as geo-location white space database in USA.



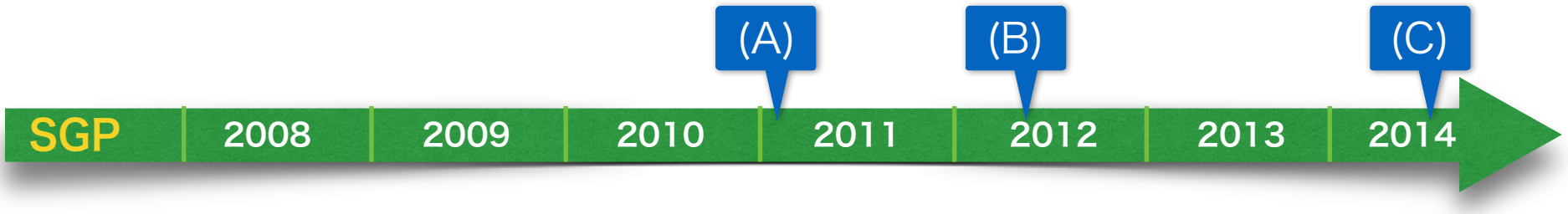
# Policy and Trails in USA

- Trial Systems in USA
  - (1) Oct 2009, the WhiteFi network developed by Microsoft Research;
  - (2) May 2011, a commercial Super Wi-Fi network was developed in Calgary based WestNet City;
  - (3) Jan 2012, the United States first public Super Wi-Fi network was developed in Wilmington based SpectrumBridge;
  - (4) July 2013, West Virginia University launches the first campus Super WiFi network.



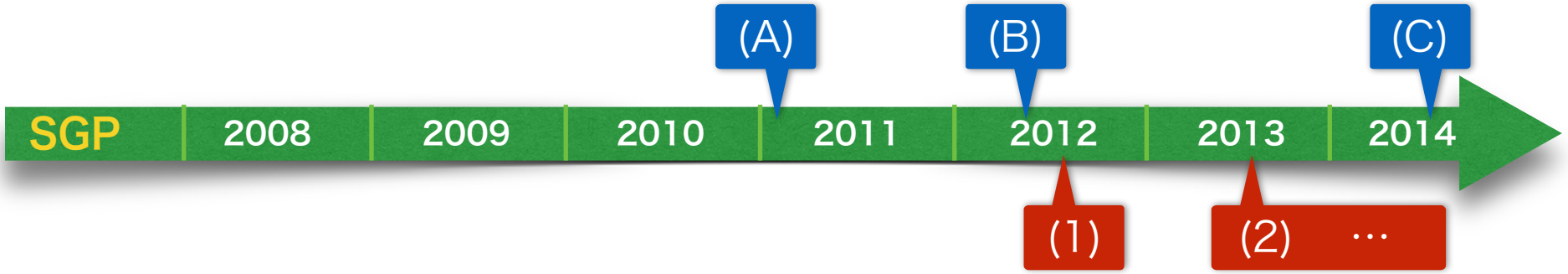
# Policy and Trails in Singapore

- Policy of IDA in Singapore
  - (A) 2011, Infocomm Development Authority (IDA) conducted a study on the commercial potential of TV White spaces.
  - (B) April 2012, the Singapore White Spaces Pilot Group (SWSPG) was established with support from IDA, to promote Singapore as a leading test-bed and innovative zone for conducting pilot projects using White Spaces.
  - (C) June 2014, IDA released the regulatory framework for TV white space, which will make available for use approximately 180 MHz of spectrum when it takes effect from Nov 2014.



# Policy and Trails in Singapore

- Pilots of SWSPG in Singapore
  - (1) April 2012, the first-in-Asia pilot projects were launched by the Singapore White Space Pilot Group (SWSPG);
  - (2) June 2013, SWSPG unveiled 4 new commercial pilots:
    - (a) Gardens by the Bay
    - (b) Sentosa
    - (c) Housing & Development Board (HDB)
    - (d) Eurokars Group.



# Policy and Trails in Singapore

- (a) Gardens by the Bay in Singapore
  - A TVWS trial allows visitors to one of Singapore’s latest tourist attractions to use Wi-Fi more reliably, without the need for the Gardens to deploy intrusive infrastructure within its boundaries and thus avoid the eyesore of wired connections. Within the Gardens, the Supertree Grove, Meadow and Canopy have already been setup to provide TVWS-enabled Wi-Fi to tourists.

- (b) Sentosa in Singapore
  - A pilot will commence on the island to provide visitors with Wi-Fi access and to enable CCTV cameras to communicate over the network at three sites: the Siloso Beach, Palawan Beach and Merlion Complex. The trial, which went live at the end of last month, will involve the participation of several TVWS providers to provide seamless connectivity

# Policy and Trails in Singapore

- (c) Housing & Development Board (HDB) in Singapore
  - Centered around CCTV enablement, deployment of TVWS will allow for better machine-to-machine communication and surveillance, and for law-enforcement authorities to obtain real-time video feeds from HDB buildings. This will eliminate the need to store video data locally and the need to deploy manpower to retrieve it regularly, while giving access to several relevant agencies to share the video data and perform real-time analytics.

- (d) Eurokars Group in Singapore
  - Focused on increasing the reach of its IT network, the car dealership will use TVWS-enabled Wi-Fi to cover a larger area while adding value-added services to its portfolio such as vehicle fleet tracking and customer arrival and service management. Microsoft Research will power the Eurokars database.

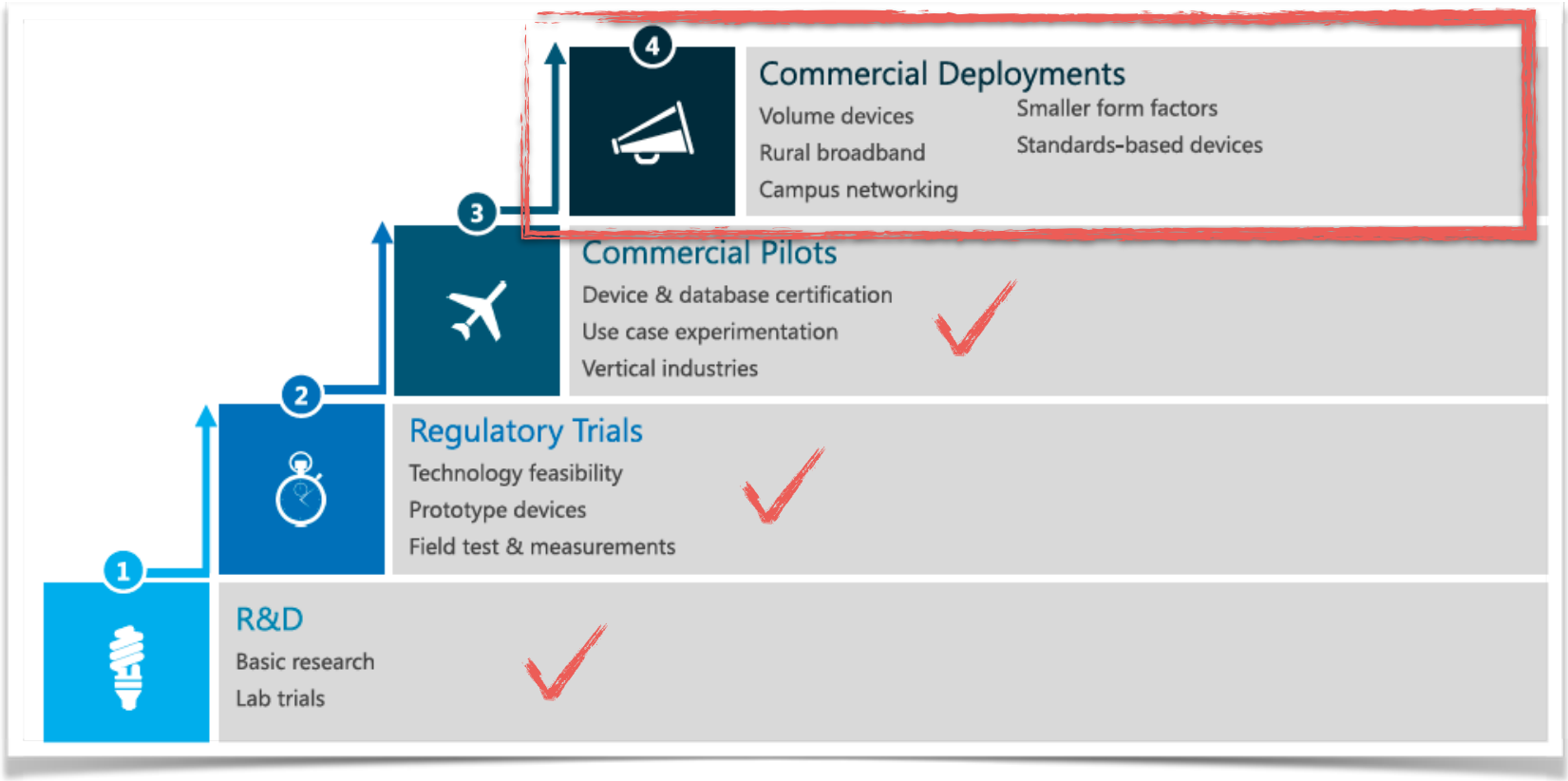
The TVWS regulatory framework is a step towards Singapore's vision on being the world's first Smart Nation.

—— Leong Keng Thai (IDA Deputy Chief Executive)

# Our Study

# State of The Art

- We are witnessing the increasing demand for spectrum and the fast development of TV white space technology.



Are we ready for the large-scale commercial deployment of TV white space networks?

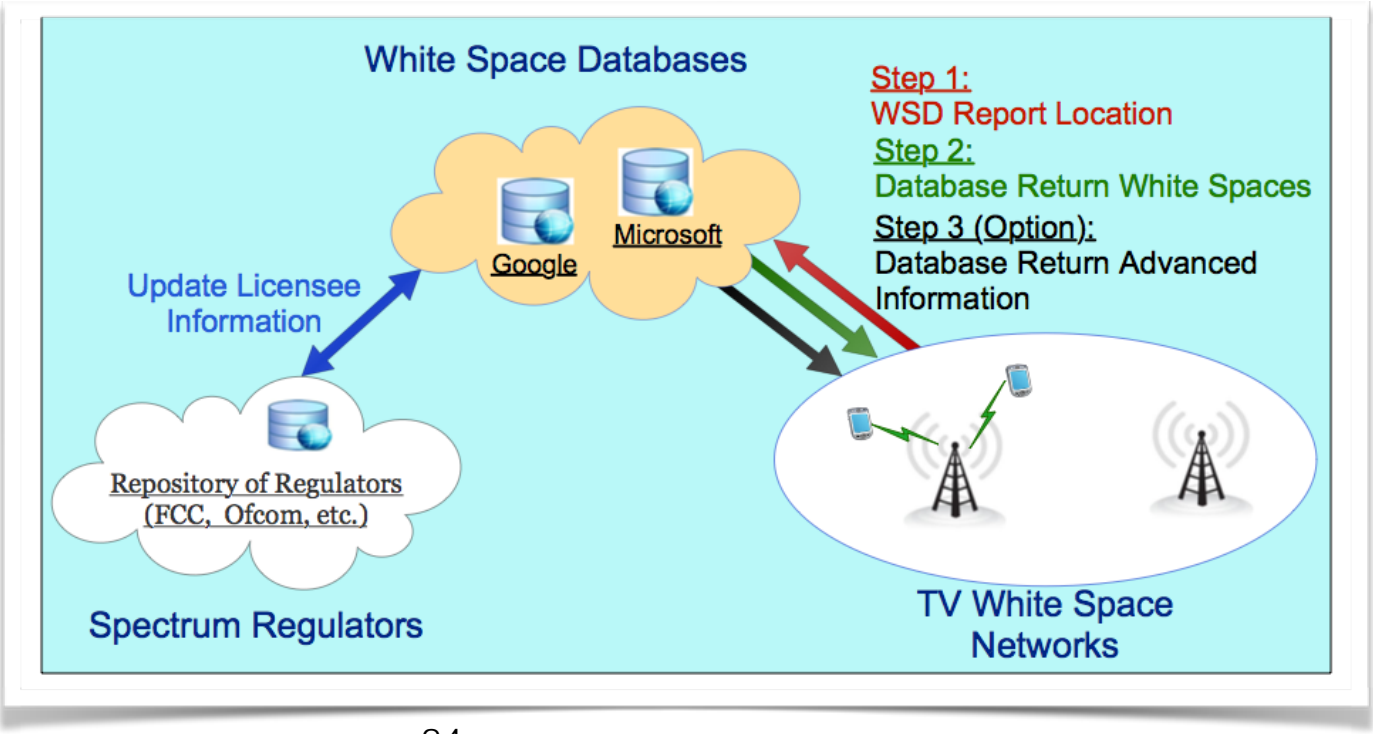
# Our Research Focus

- **Business Modelling and Analysis** of TV White Space Networks
  - Propose and analyze TV white space market models;
  - Understand the economic behaviours of different players;
  - Understand the evolution of TV white space markets.

- Motivation: The large-scale commercial deployment of TV white space network requires a proper business model and comprehensive economic analysis.

# Our Work 1

- In [3], we propose and analyze an Information Market Model for TV white space networks.
  - Key Idea: Encourage white space databases sell the advanced information to white space users;
  - Received the Best Paper Award in IEEE WiOpt 2014



# Our Work 2

- In [4], we propose and analyze a Broker-based Spectrum Market for TV white space networks.
  - Key Idea: Database reserves TV white spaces from TV broadcasters, and resells to TV white space networks;
  - Published in IEEE J. on Selected Areas in Commu. (JSAC), 2014

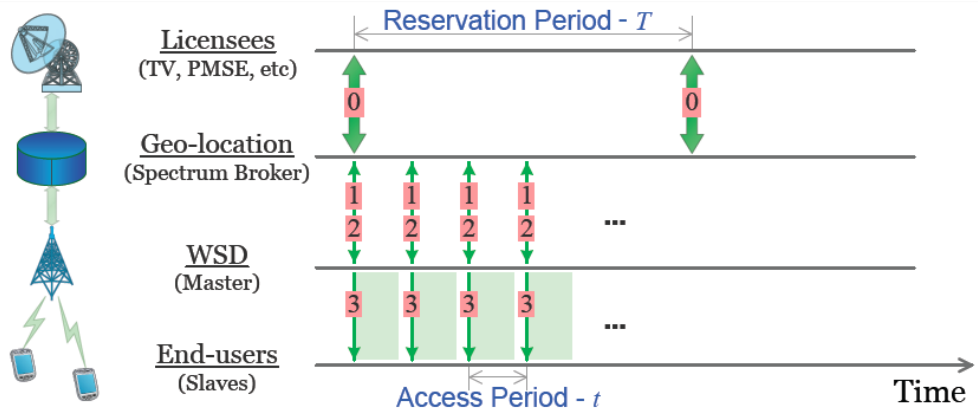
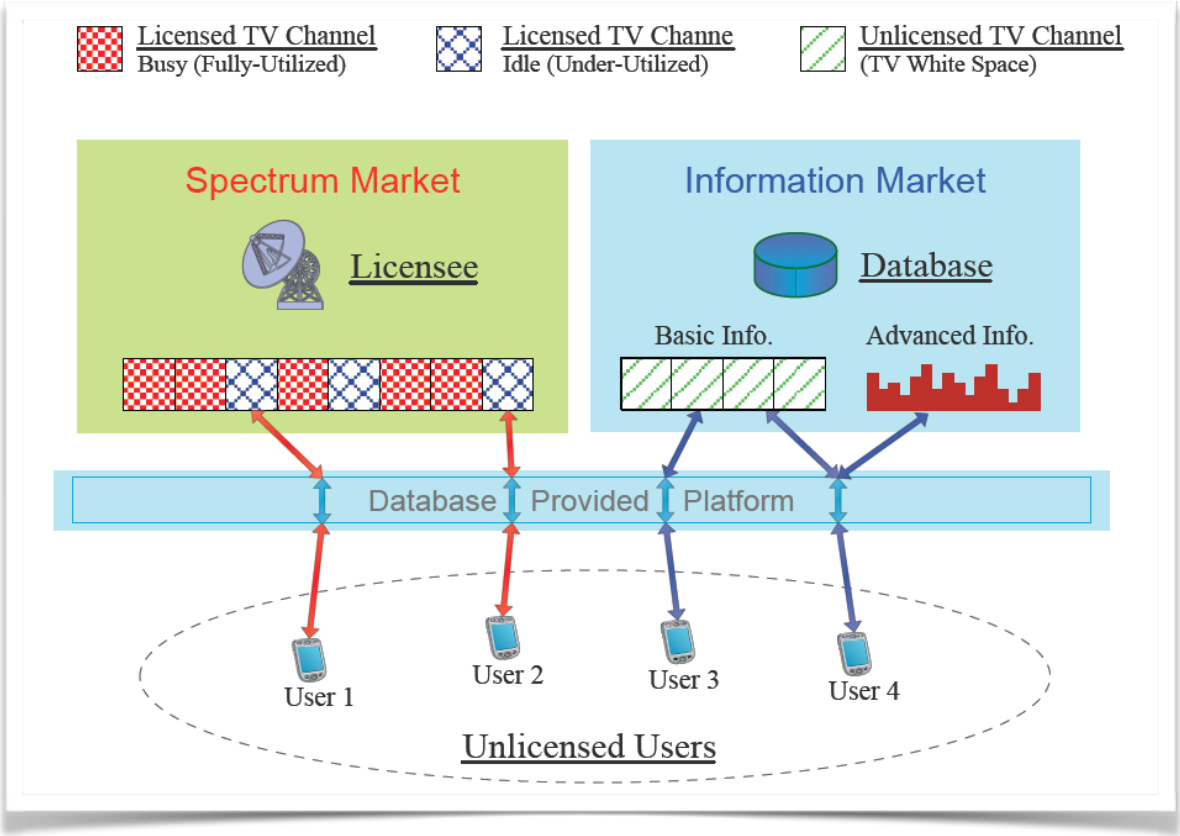



Figure 2. Spectrum reservation and access processes. Step 0: the database reserves spectrum for every $T$; Step 1: the master reports the realized demand in every $t$; Step 2: the database returns spectrum to the master in every $t$; Step 3: the master serves end-users in every $t$.

# Our Work 3

- In [5], we propose and analyze a Hybrid Spectrum and Information Market for TV white space networks.
  - To appear in IEEE INFOCOM, 2015



# Summary

The technology is becoming mature.

The ecosystem is ramping up quickly.

The business model is lagging behind.

Great time for deciding Hong Kong's own policy.

# Thank You

# Reference


- [1], X. Ying, J. Zhang, L. Yan, G. Zhang, M. Chen, and R. Chandra, "Exploring Indoor White Spaces in Metropolises", ACM MobiCom, 2013.
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- [3] Y. Luo, Lin Gao, and J. Huang, "Trade Information, Not Spectrum: A Novel TV White Space Information Market Model," IEEE WiOpt (Best Paper Award), 2014.
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