TV White Space Technologies and Social Deployments

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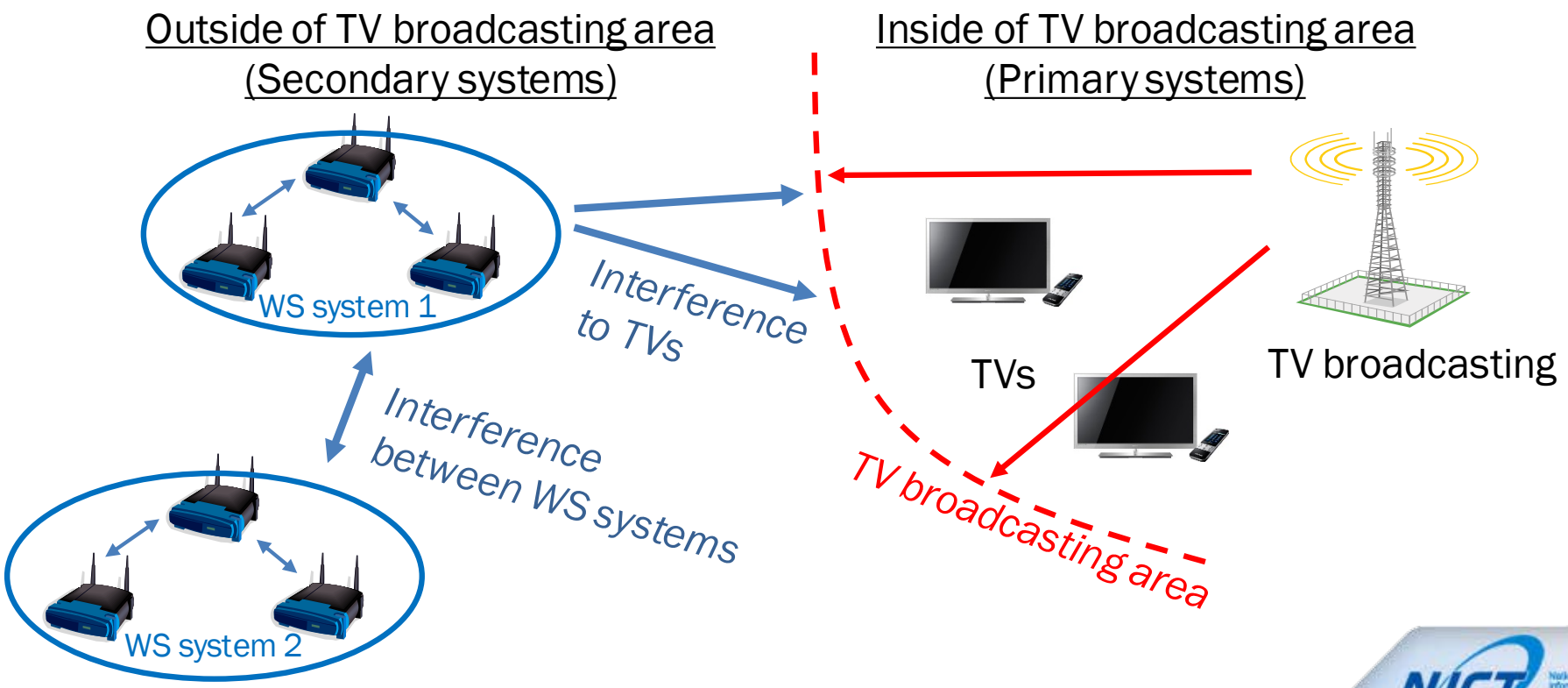
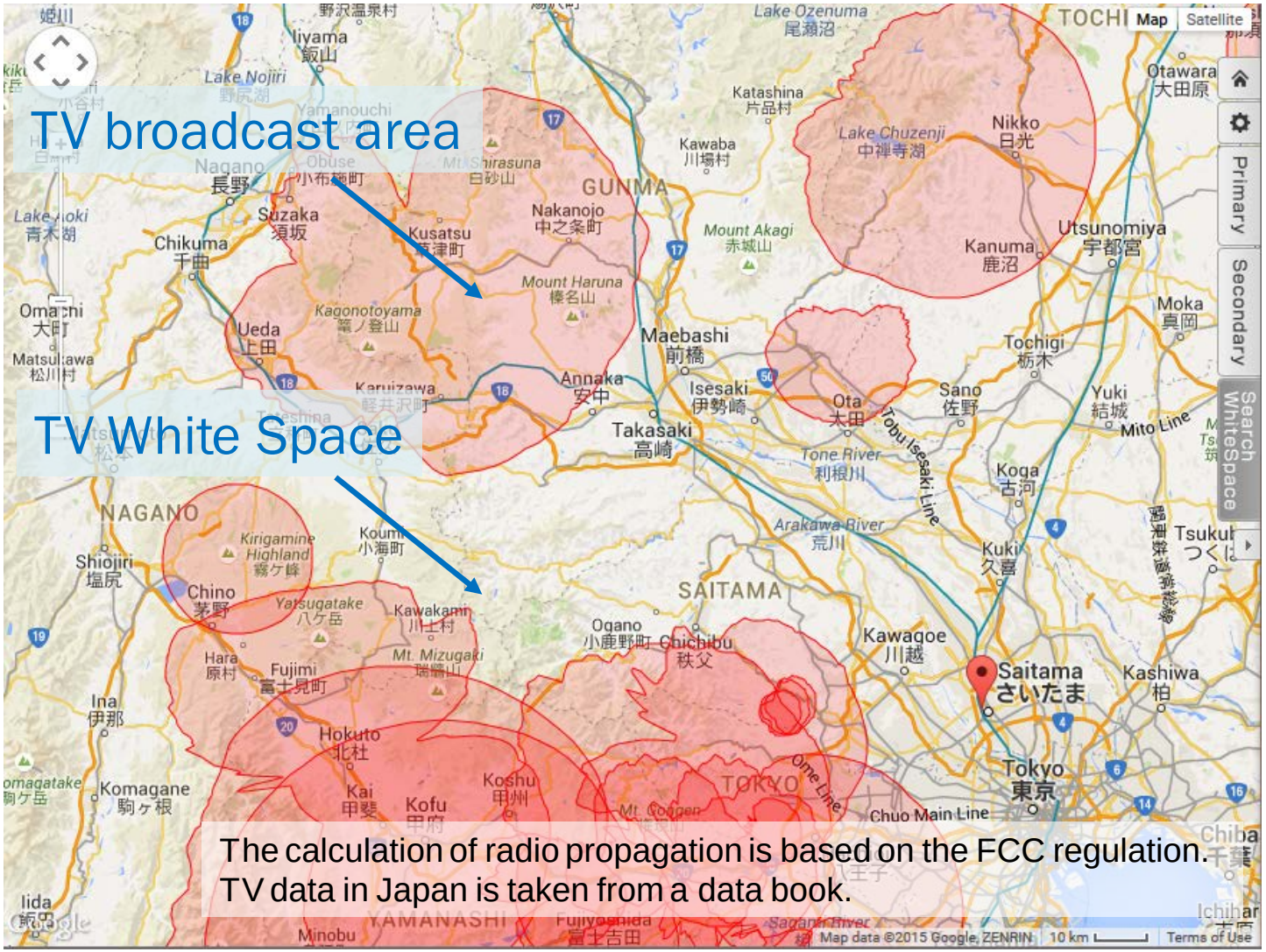
Concept of TV White Space

- TV White Space (TVWS) is used without interference to primary systems (TV broadcasts).
- TVWS band have a good feature in radio propagation.
- TVWS is expected to improve the spectrum utilization efficiency.

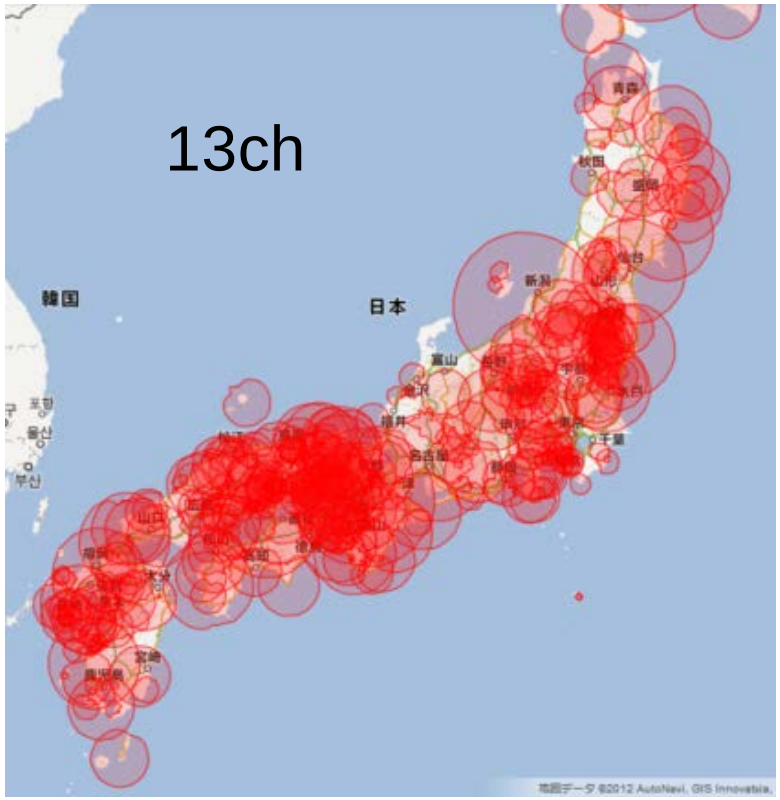


Availability of TV White Space



The calculation of radio propagation is based on the FCC regulation.
TV data in Japan is taken from a data book.

Availability of TV White Space



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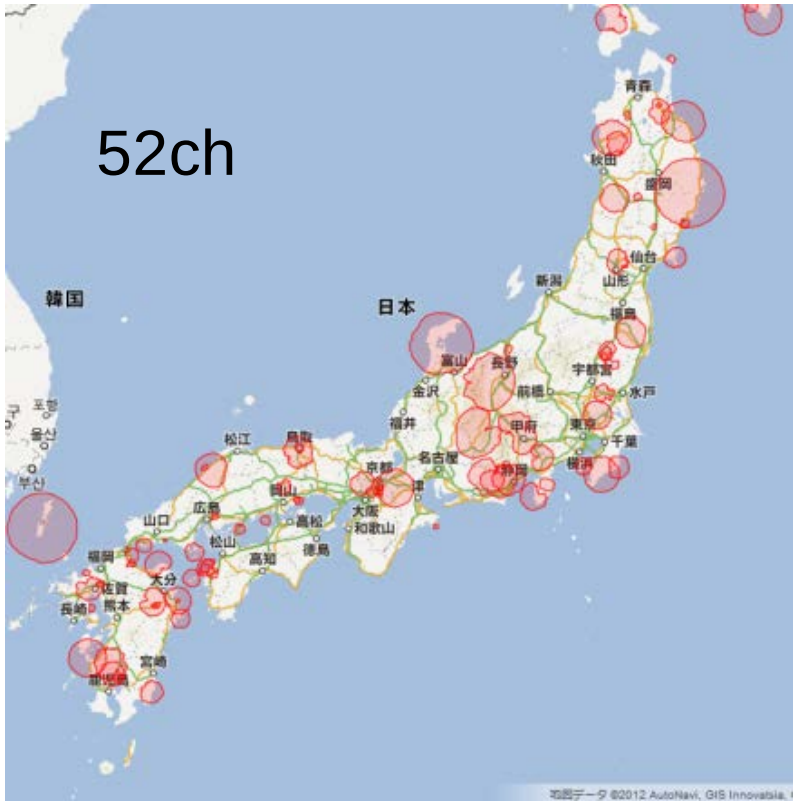
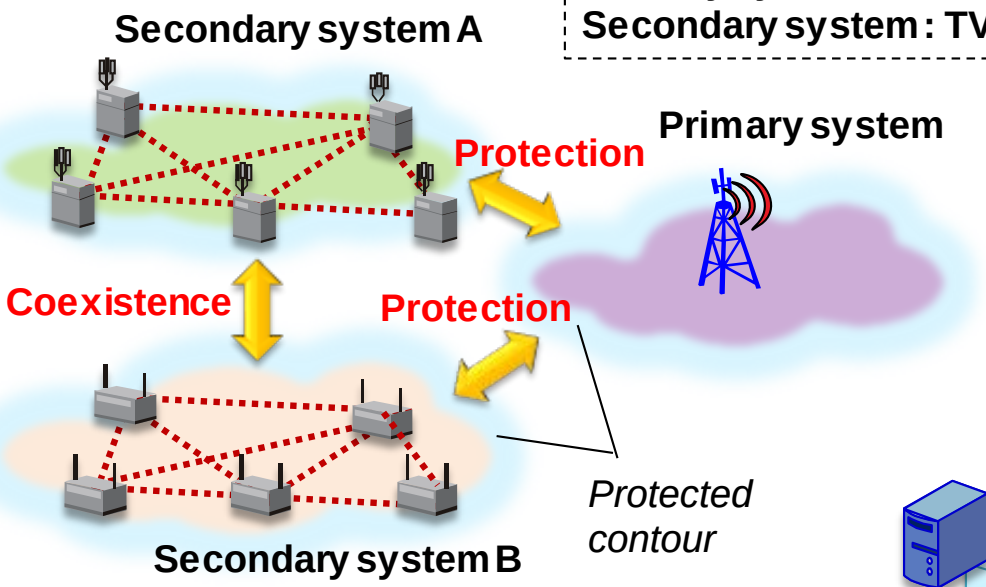


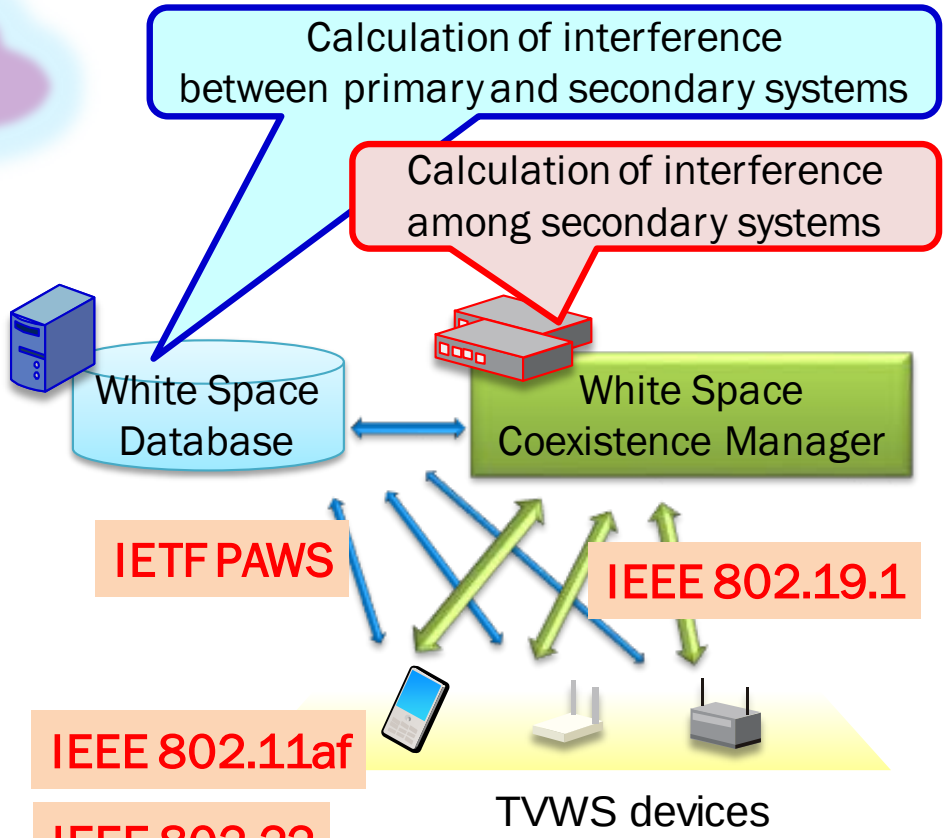
Availability of TVWS is different from location to location.
Occupancy of each channels is different.
Some technologies are required to find the TV White Space.

The calculation of radio propagation in the Figures is based on the FCC regulation. TV data in Japan is taken from a data book. The availability of TVWS above is just an example.

Necessity of Standardization

Primary system : TV broadcasts
Secondary system : TV White Space communications



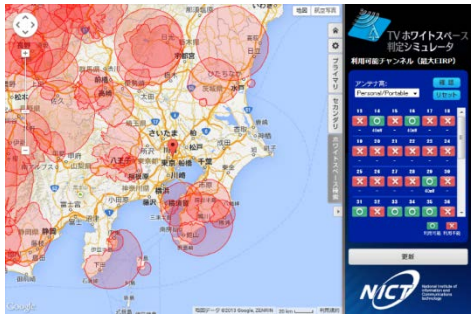


Standardization of technology
- Interoperability of products
- Scalability of utilization
- Expansion of business

Overview of TVWS technologies of NICT

Qualified by Ofcom, U.K.

Adopted by Philippines



TV White Space Database

Engine (U.S. FCC) | Engine (U.K. OFCOM) | Engine (Japan) | Engine (Philippines) | Engine (Singapore)

I/F (IETF PAWS)

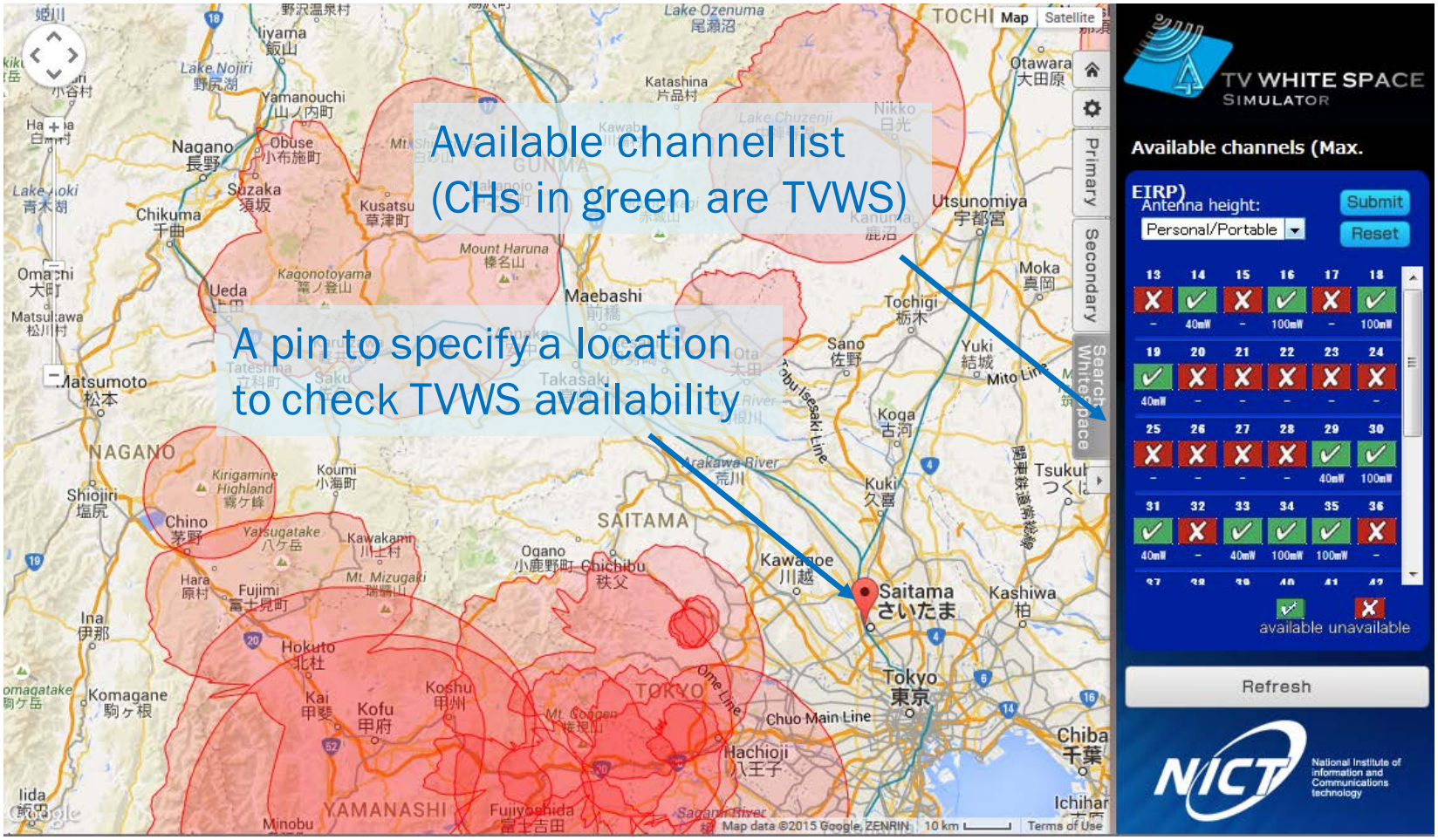
Plug-in

Engine (Others)

I/F (PAWS)	I/F (PAWS)	I/F (PAWS)
Engine (RLSS)	Engine (Spectrum Manager)	Engine (Manager)
IEEE 802.11af	IEEE 802.22	White Space LTE

Spectrum mask satisfied (FCC, ETSI)

White Space Database (WSDB)



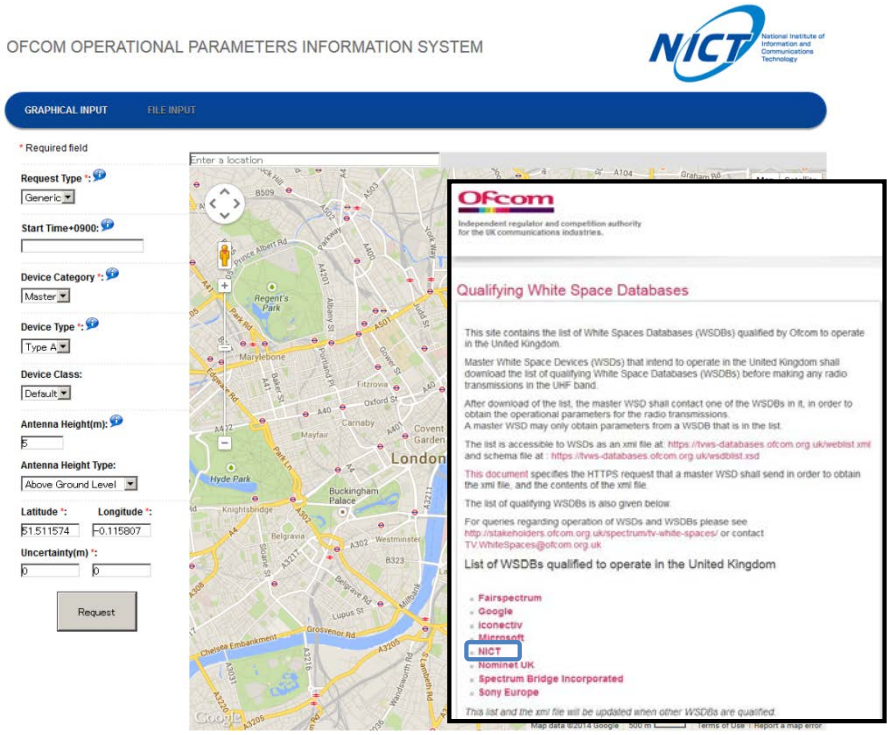
- WSDB calculates interference of secondary systems to primary systems according to radio propagation models based on geography.
- Then, availability of TV channels are determined based on interference level at each location.

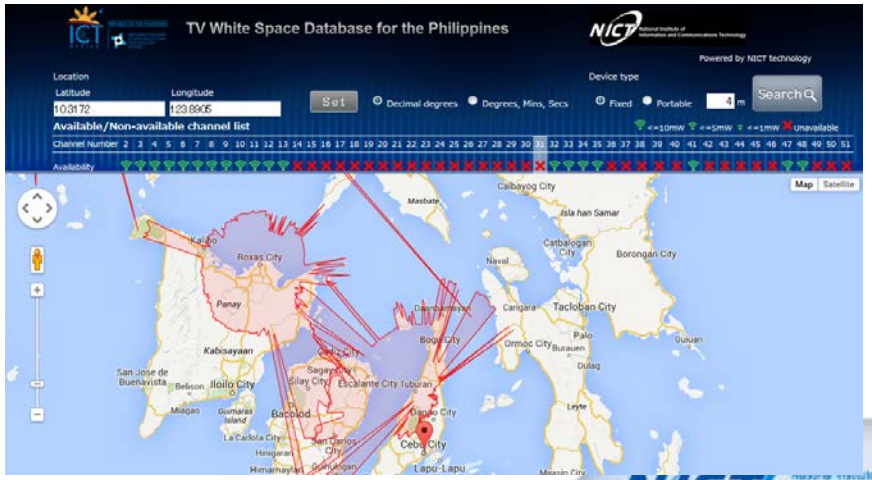
Deployment of TVWS Database

- Qualified by U.K. Ofcom for its TVWS Pilot project.
  - Real time management to protect higher priority systems, i.e. radio mic operations in TVWS

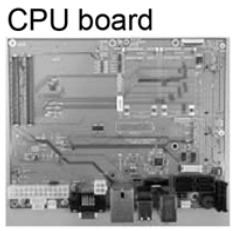
- Adopted by ICTO of Philippines for its Free Wi-Fi Project.
  - Press release on May 7, 2015

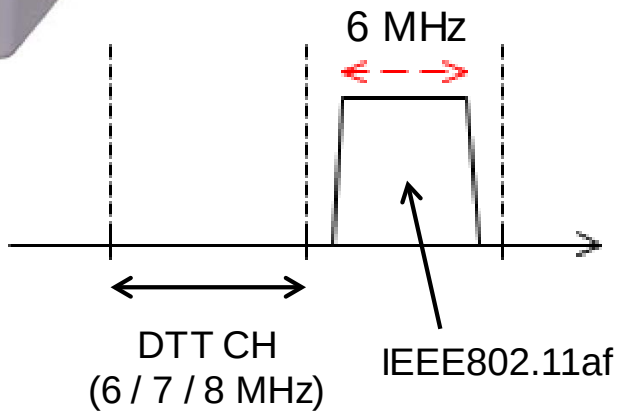
- Licensed by Singapore IDA for experimental TVWS operation.





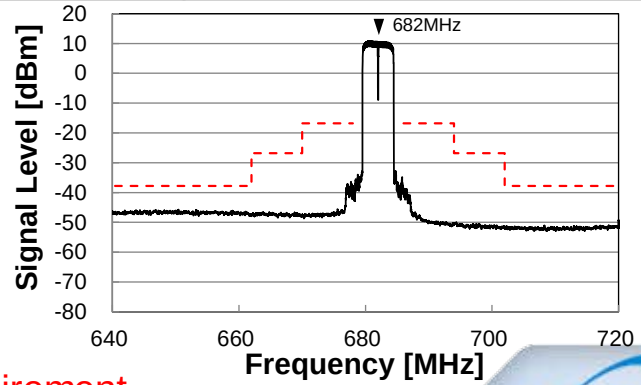
IEEE 802.11af system





Item	Description
Frequency range	470-710 MHz / 500~710 MHz
Channel bandwidth	6 MHz
Channel step	1MHz
Signal bandwidth	4.83 MHz
Frequency accuracy	±2 ppm
Tx power	+10 / +30 dBm
Tuning range of output power	> 40 dB
Receiving signal PWR range	−88 ~ −20 dBm
Modulation	BPSK, QPSK, 16-QAM, 64-QAM
Error correction	Convolutional code (coding rate: 1/2,2/3,3/4,5/6)
Multiple access	CSMA/CA
Multiplexing	OFDM
FFT size/clock	128 points / 5.33 MHz

	ACLR (dB)				
Device class	1	2	3	4	5
$n = \pm 1$	74	74	64	54	43
$n = \pm 2$	79	74	74	64	53
$n \geq +3, n \leq -3$	84	74	84	74	64



ACLR (Adjacent Channel Leakage Ratio) conforms with ETSI requirement.

LTE system for TVWS

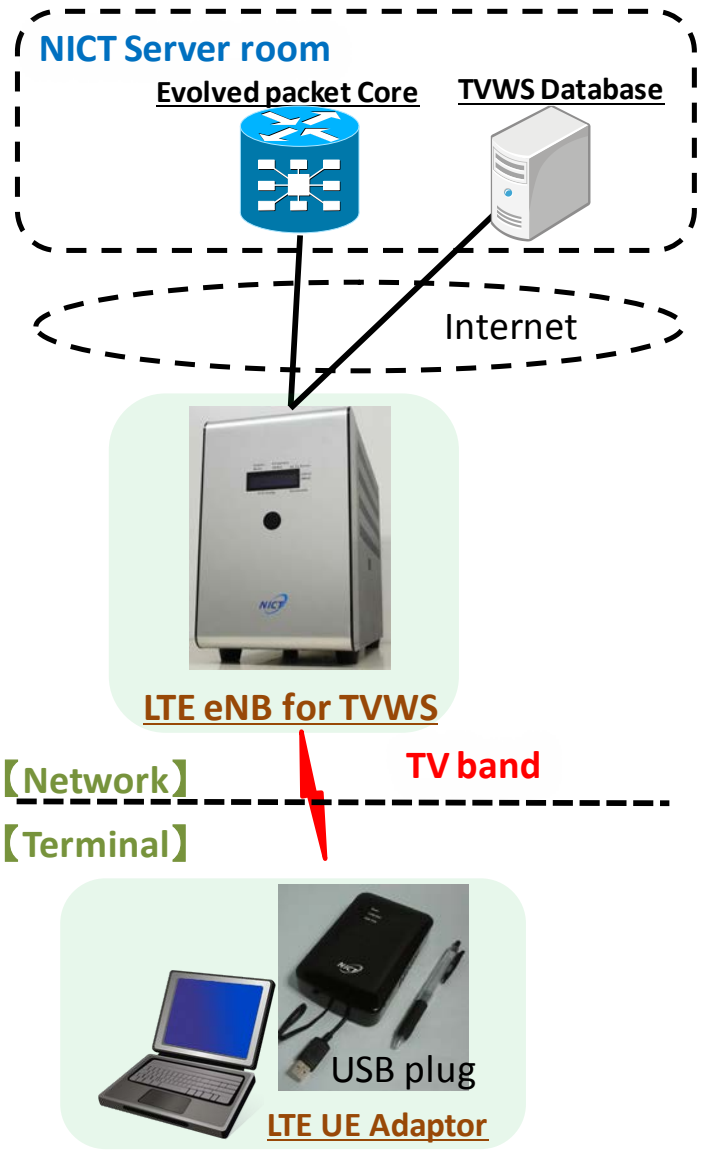
- Ready to operate in TVWS.
- Reconfigurable bandwidth (5/10/20 MHz) according to traffic congestion and TVWS availability.

Spectrum masks of the devices satisfy the ETSI regulation on out-of-band emission.

Femto cell eNB
for portable deployment

Smartphone
supporting both commercial and TVWS bands

Wireless router
to convert between LTE in TVWS and Wi-Fi in 2.4/5GHz



Trial in Japan (P2P over long-distance)

IEEE802.22 system was used in this trial. (TDD mode)

Takashimizu

BS
EIRP：3. 8W

CPE
EIRP：966mW

CPE
EIRP：3. 8W

Sadato

DS: 5.2Mbps(64-QAM r=1/2)

12.7 km (LoS)

US: 4.5Mbps(64-QAM r=1/2)

US:9.0Mbps
(16-QAM, r=3/4)

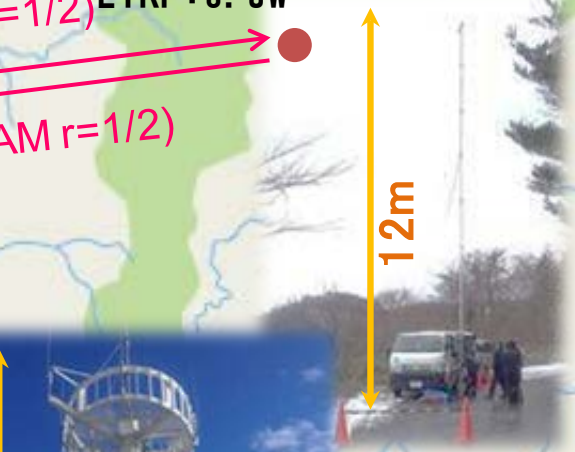
6.3 km (LoS)

DS:15.5Mbps
(64-QAM, r=3/4)

2 channels used

BS
EIRP：2. 9W

Fire station



This experiment was conducted jointly with Hitachi Kokusai Electric.

Trial in London (P2P in metropolitan area)

IEEE802.11af system was used in this trial.

3-element Ring Yagi (7.4dBi)

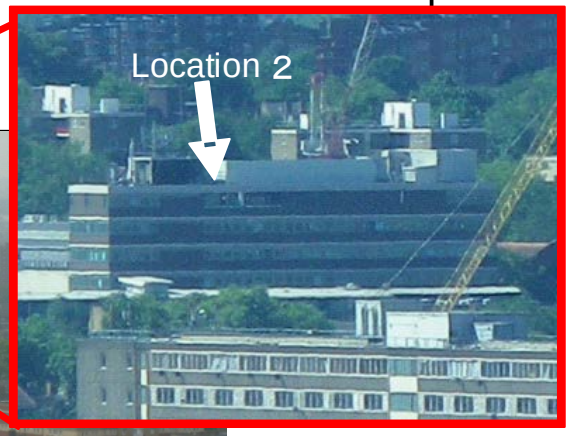
The Thames River

London Bridge

Waterloo

more than 2Mbps over 3.7 km

Denmark Hill

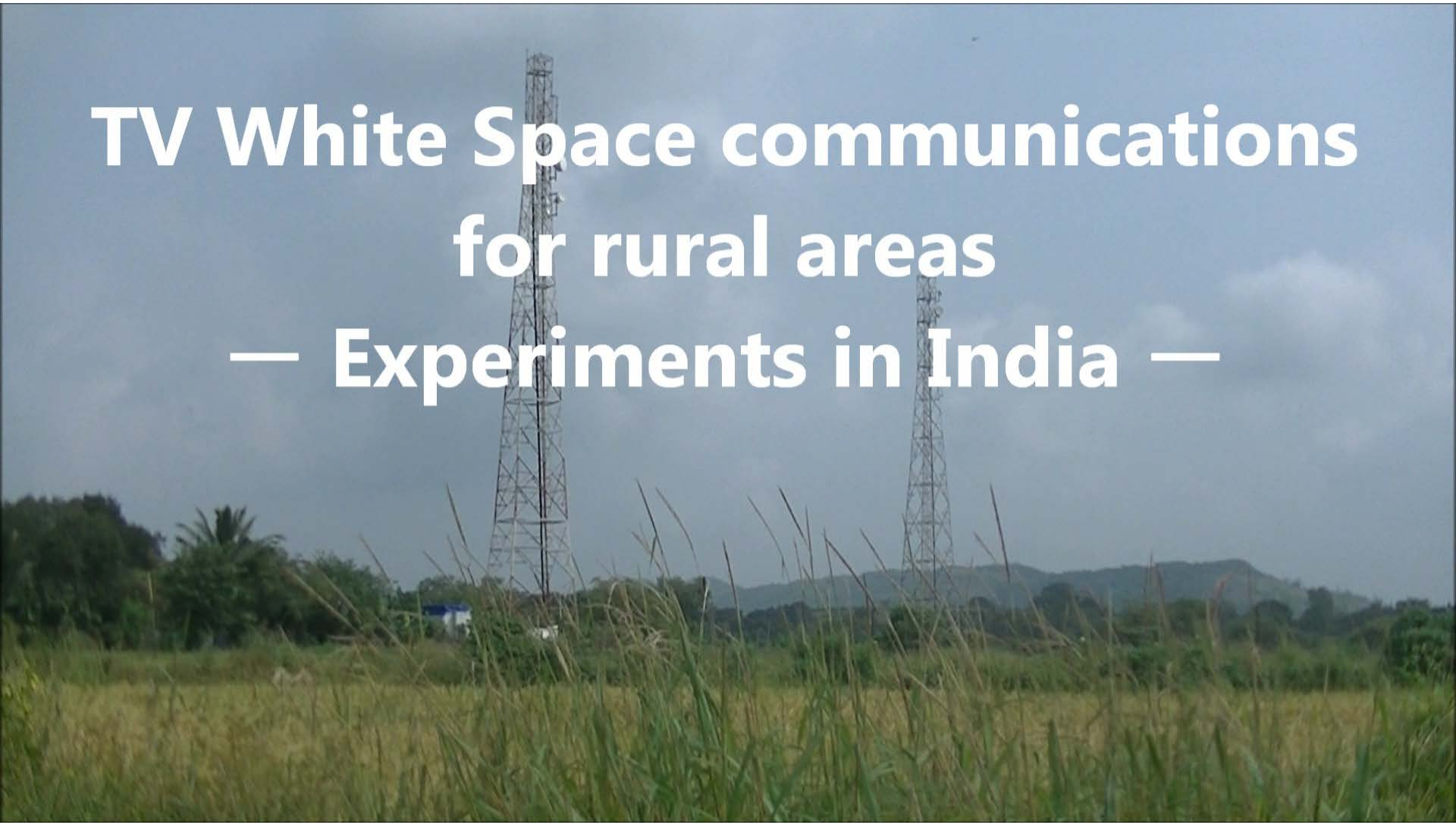


This experiment was conducted with Dr. Oliver Holland and his colleagues from King's College London.

Trial in India (Solution to digital divide problem)

- In India, residential area is organized from very small unit of villages
- Not practical to deploy cables to homes
  - Internet is NOT available just 50 km away from the metropolitan area
  - Even phone call is difficult depending on locations
- Trial
  - Motivation: TV White Space could be a solution to the digital divide problem
  - Collaborative research with IIT Bombay
  - Using White Space LTE system

Trial in India (Solution to digital divide problem)



Conclusions

- Technologies and standardizations are ready to start up operations in TV White Space
  - Feasible deployments
    - Point-to-Point link (front-haul/back-haul)
    - Mobile communications
  - Solutions expected
    - Traffic off-loading from commercial 3G/4G (LTE) bands
    - Mitigation of Digital divide problem

- **<u>What is next step?</u>**
  - to check feasibility and issues in various use cases according to demands and circumstances in each country
  - to consider radio regulations and business deployment scenarios