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University of Bristol, Bristol – UK.

The UK framework for access to white spaces in the UHF TV band

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The contents of this presentation represent the views of the author and do not necessarily reflect Ofcom policy.

Outline

- What are TV white spaces?
- Database assisted access and eco-system
- Protection of DTT and PMSE
- Harmonisation and standardisation
- Conclusions

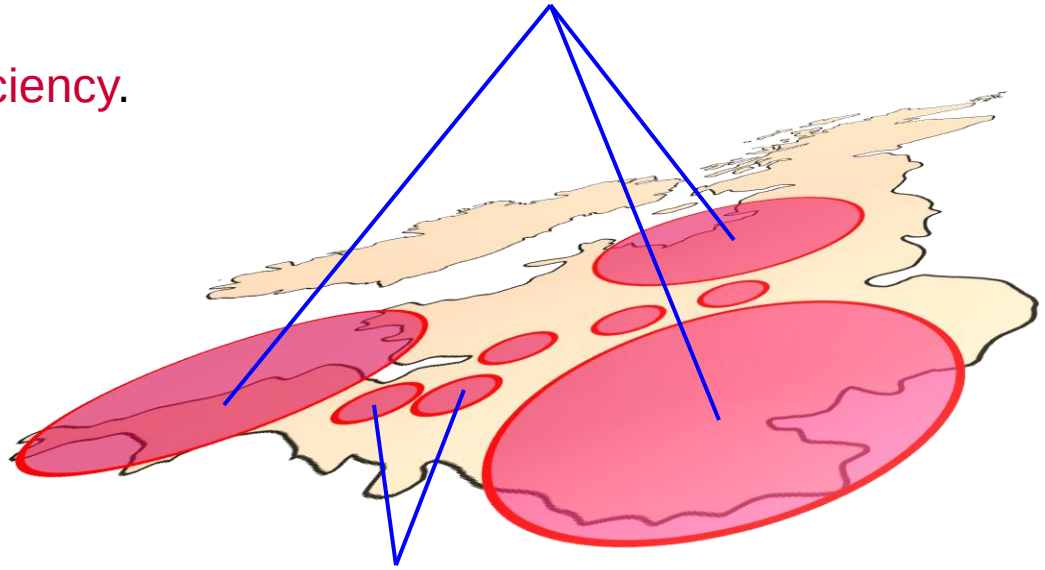
TV white spaces

- "*White spaces*" refer to geographical areas where the radio spectrum is not used by the licensee.

- White space spectrum can be potentially accessed by users other than the licensee, resulting in
  - increased overall spectrum efficiency.
  - innovative new services.

- Protection of the incumbent licensee(s) is paramount.

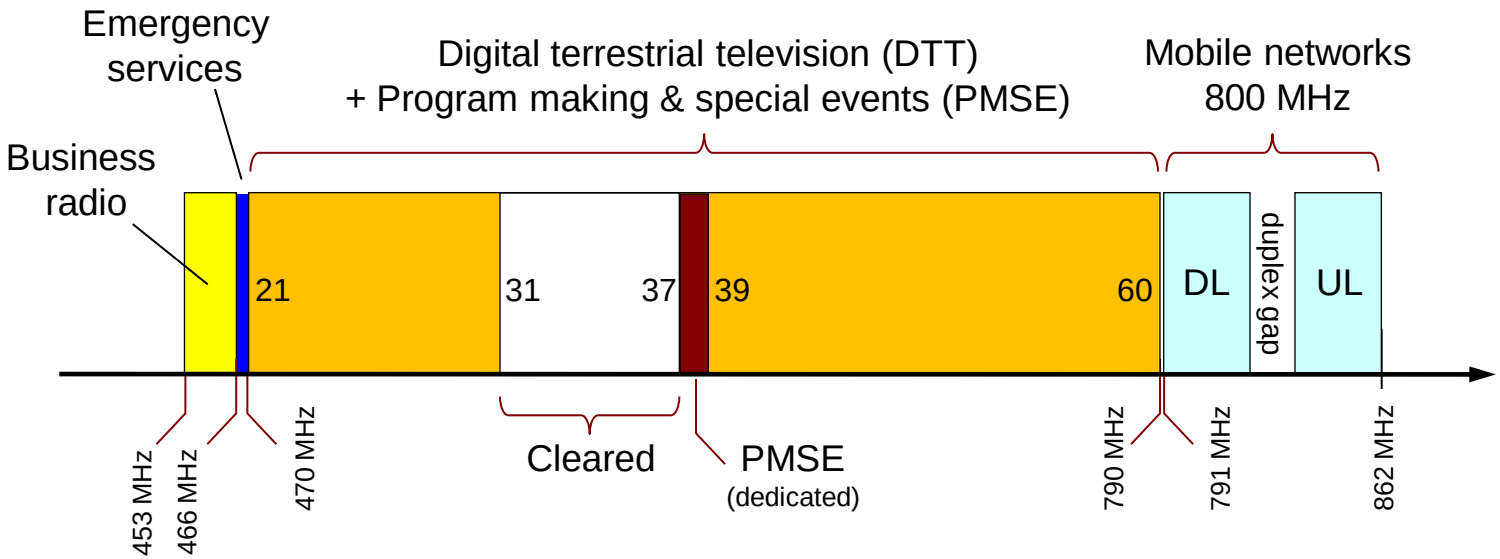
High power TV broadcasts using the same frequency need to leave spaces between their coverage areas to avoid interference.



These frequencies can be used in the "white spaces" in between by lower-power devices.

The UHF TV band and licensed services in the UK

- Access to the UHF TV band by white space devices (WSDs) would be subject to the protection of incumbent licensees.



- We should not forget cross-border obligations.

The path towards access to TV white spaces

Ofcom's consultations

White space access should be allowed in principle and be licence exempt, provided no interference is caused to licensed services.

Initial views on white space database ownership, information exchange between databases and WSDs.

Autonomous vs. database-assisted.

Geolocation was the most promising way for a WSD to gain access to spectrum in the short-medium term. Sensing is also an option in the longer-term.

Initial views on approach to making WSDs licence exempt, high-level requirements on databases and database providers.

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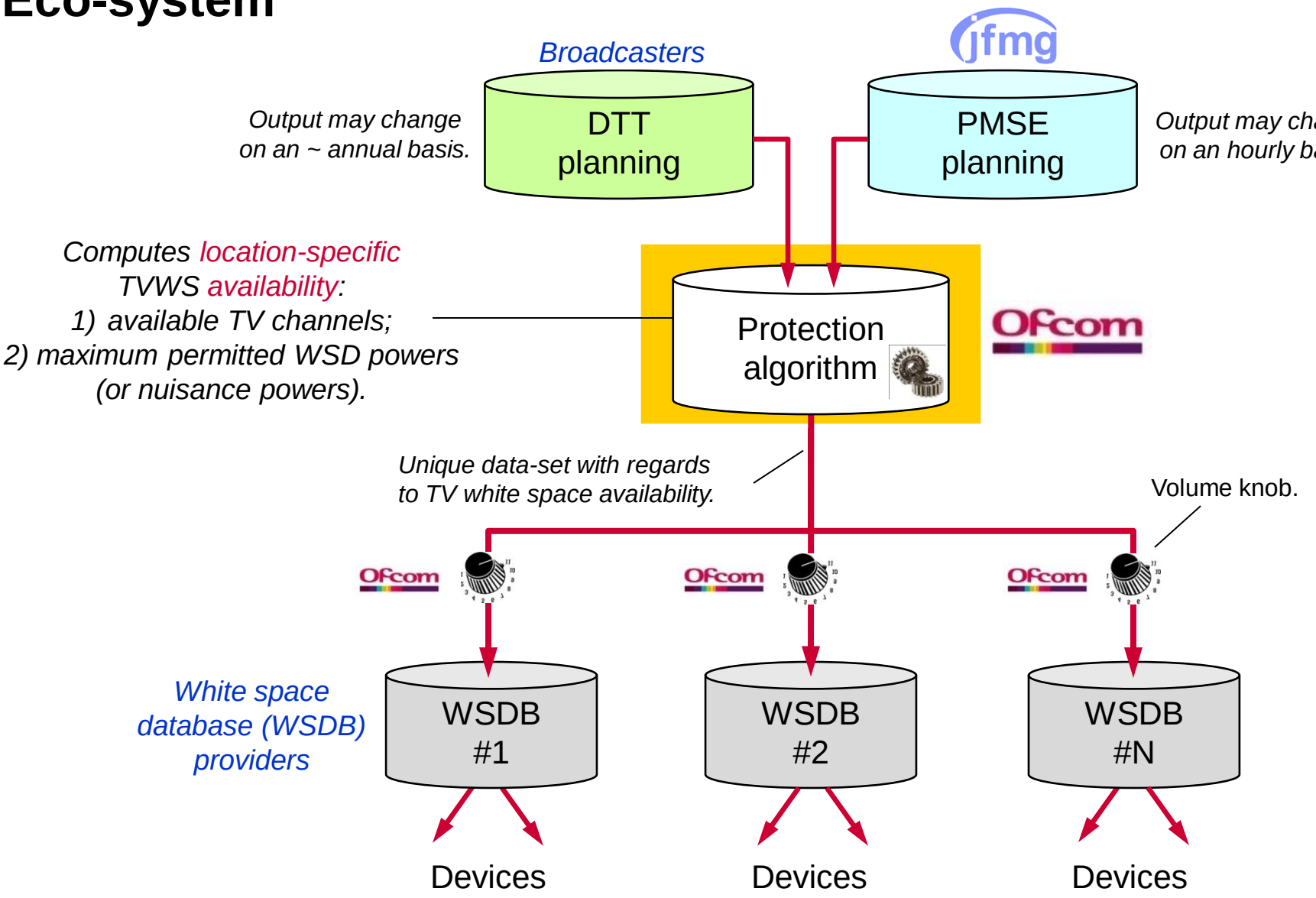
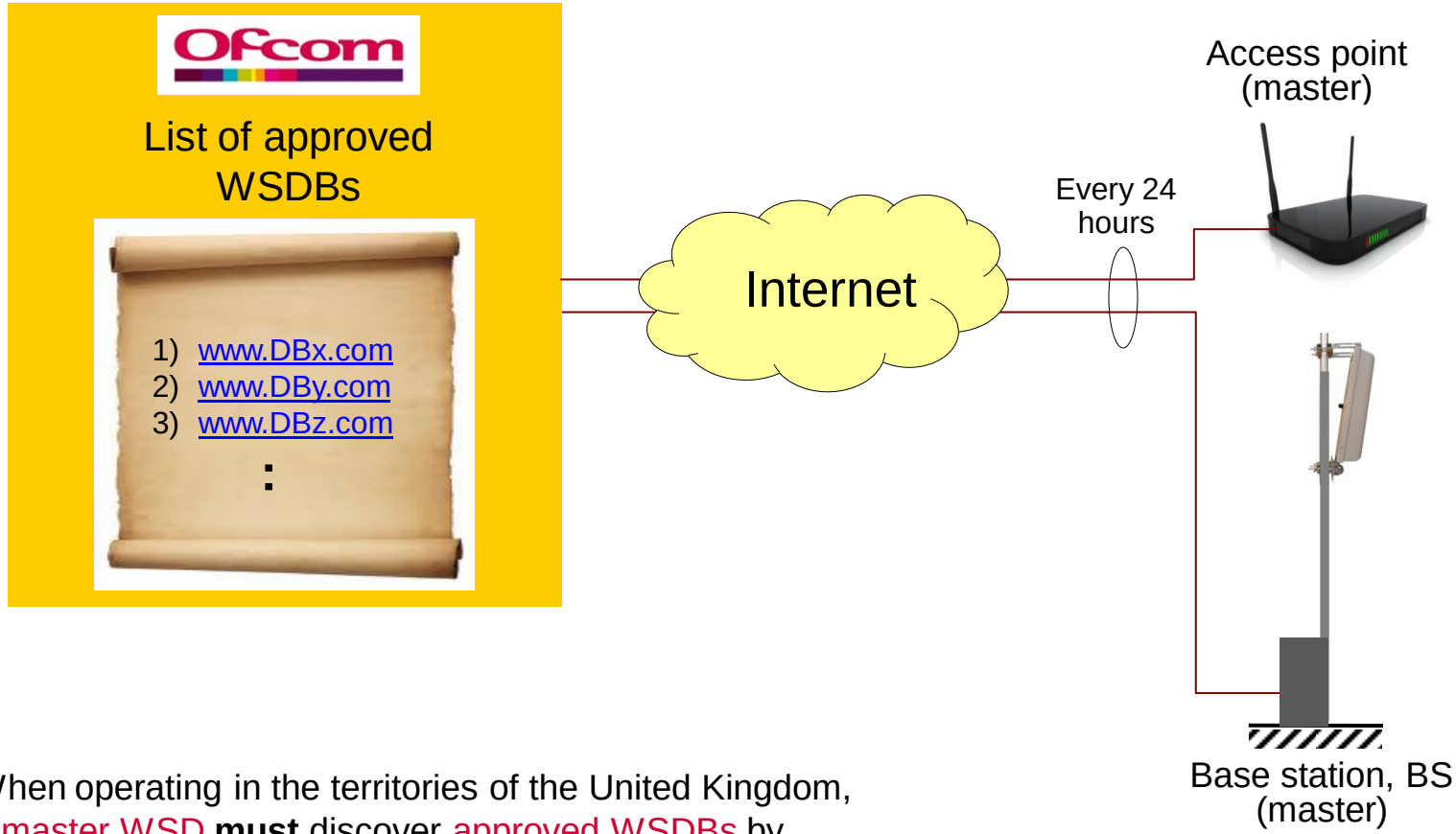
Eco-system


Broadcasters
jfmg
Output may change on an ~ annual basis.
DTT planning
PMSE planning
Output may change on an hourly basis.
Computes location-specific TVWS availability:
1) available TV channels;
2) maximum permitted WSD powers (or nuisance powers).
Protection algorithm
Ofcom
Unique data-set with regards to TV white space availability.
Volume knob.
White space database (WSDB) providers
WSDB #1
WSDB #2
WSDB #N
Devices
Devices
Devices

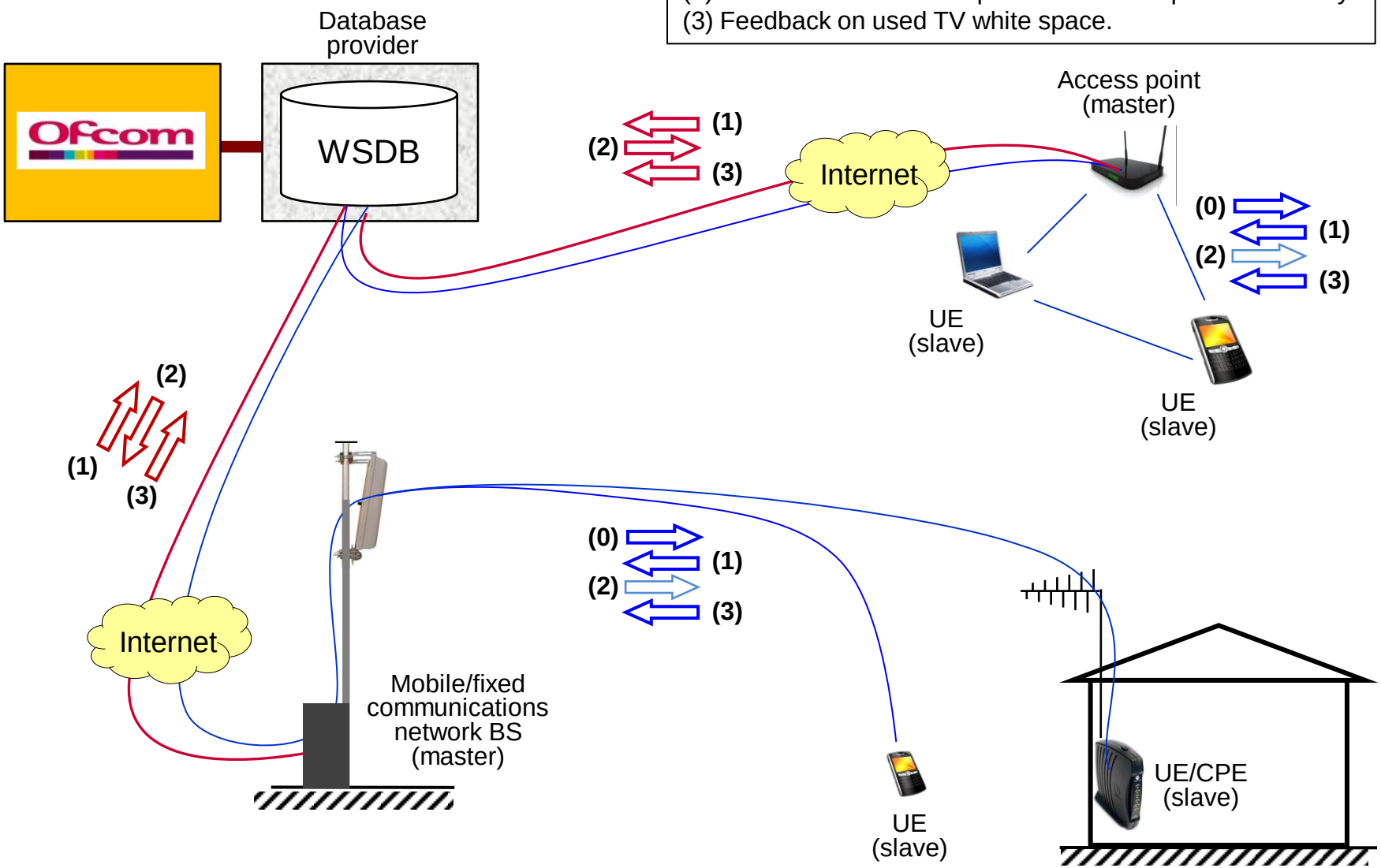
Database “discovery”



- When operating in the territories of the United Kingdom, a master WSD **must** discover approved WSDBs by consulting a website maintained by Ofcom which holds a list of approved WSDBs. This requirement applies unless the master WSD has consulted the website within the last 24 hours.

Communications

(0) Broadcast info on TV white space availability.
(1) Report device attributes (e.g., location, device class).
(2) Communicate device-specific TV white space availability.
(3) Feedback on used TV white space.



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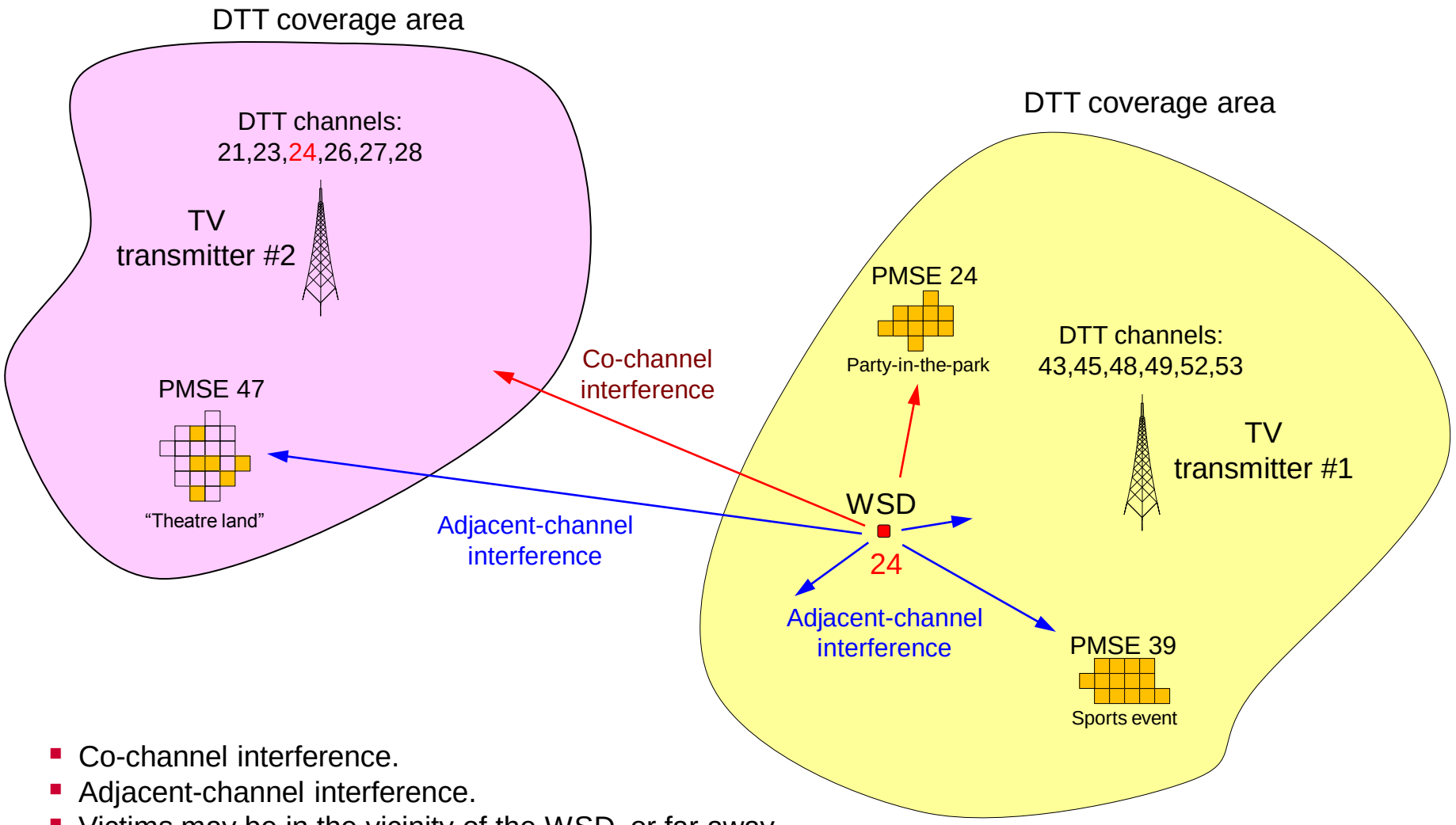
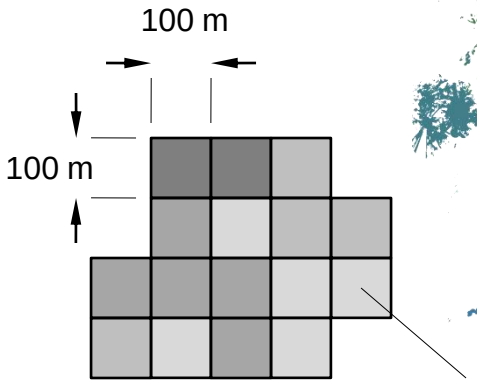
Interference: An illustration



- Co-channel interference.
- Adjacent-channel interference.
- Victims may be in the vicinity of the WSD, or far away.

DTT: How are DTT networks planned?

- For each 100m x 100m pixel, broadcasters calculate a DTT location probability, q.
- Writing in the linear domain,



DTT location probability

q

DTT receiver reference sensitivity

$$q = \Pr\left\{ P_S \geq P_{S,\min} + \sum_{k=1}^{K} r_{U,k} P_{U,k} \right\} = \Pr\{P_S \geq U\}.$$

Received DTT wanted signal power (log-normal)

DTT-to-DTT protection ratio

Received DTT unwanted signal power (log-normal)

DTT: What happens when a WSD radiates?

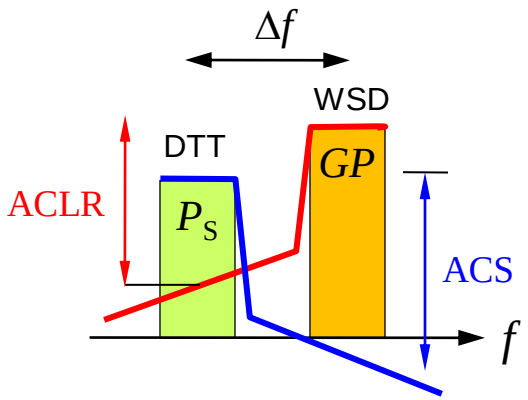
- DTT location probability reduces:

WSD in-block (carrier) EIRP

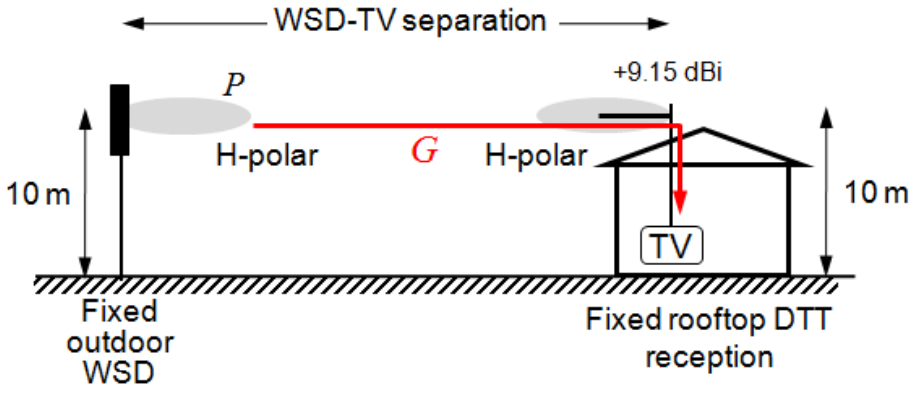
$$q' = q - \Delta q = \Pr\left\{ P_S \geq U + r(\Delta f, P_S) \; G \; P \right\}$$

WSD-to-DTT protection ratio

WSD-to-DTT coupling gain (log-normal)



Protection ratio, r, is ratio of wanted power over interferer power at the point of receiver failure and depends on:
a) interferer's adjacent channel leakage ratio, and
b) victim's adjacent channel selectivity.



DTT: Derive permitted WSD EIRP

- For a target reduction in location probability, Δq_{T} the WSD in-block EIRP, P, should be such that:

$$q' = q - \Delta q_{\mathrm{T}} = \Pr\left\{ P \le \frac{P_{\mathrm{S}} - U}{r(\Delta f, P_{\mathrm{S}})\, G} \right\}$$

- This is a non-linear problem.
- A number of algorithms have been developed (by Ofcom[1,2], BBC, and others) for the solution of the above equation.
- A value for P must be calculated for each pixel across the UK, accounting for all co-channel and adjacent-channel interference constraints. See later.

1 H.R.Karimi, "Geolocation databases for white space devices in the UHF TV bands: Specification of maximum permitted emission levels," in *Proc. Dynamic Spectrum Access Networks* (DySPAN), May 2011, Aachen – Germany.

2 V.Petrini, H.R.Karimi, "TV white space databases: Algorithms for the calculation of maximum permitted radiated power levels," submitted to *Dynamic Spectrum Access Networks* (DySPAN), Oct. 2012, Bellevue, Washington – USA.

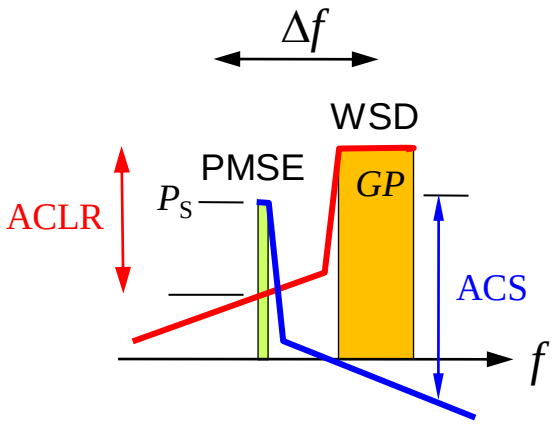
PMSE: What happens when a WSD radiates?

- Consider that a WSD radiates with an in-block EIRP of P. If G is the interferer-victim coupling gain, the operation of the PMSE receiver will not be affected if

$$P_S \geq r(\Delta f, P_S)\ G\ P\ ,$$

$$\gamma\ P_{S,\min} \geq r(\Delta f, P_S)\ G\ P\ ,$$

$$P \leq \frac{\gamma\ P_{S,\min}}{r(\Delta f, P_S)\ G}\ ,$$



where

$r(\ )$ is the WSD-to-PMSE protection ratio (i.e., ratio of wanted power to interferer power measured at the receiver and at the point of failure), and

Δf is the frequency separation between the WSD and PMSE signals.

Bringing it all together…

- **Objective:** Calculate maximum permitted EIRP, $P_{\max}(l_i, n)$, for a WSD to radiate inside pixel location l_i, and in DTT channel n, while protecting DTT and PMSE reception in all channels, $m = 1 \ldots M$.

1) Identify all[1] K populated victim pixels served in channel m.

2) Calculate the maximum permitted WSD EIRPs, $P_{0,k}(l_i, n, m)$ and $P_{1,k}(l_i, n, m)$ $k = 1 \ldots K$, for protection of DTT and PMSE in the K victim pixels in (1), respectively. See earlier slides.

3) Select the smallest of the $2K$ values calculated in (2):

$$P(l_i, n, m) = \min_k \left\{ P_{0,k}(l_i, n, m),\ P_{1,k}(l_i, n, m) \right\}.$$

4) Repeat (2)-(3) for all DTT channels m = 1….M. Then, $P_{\max}(l_i, n) = \min_m P(l_i, n, m)$.

- For a UK-wide picture, repeat (1)-(4) for all WSD locations location l_i, and all DTT channels n.

[1] Strictly speaking, steps (1) and (2) above need only be performed for the *most susceptible* victim pixel (as opposed to all populated victim pixels). This can reduce computational complexity significantly.

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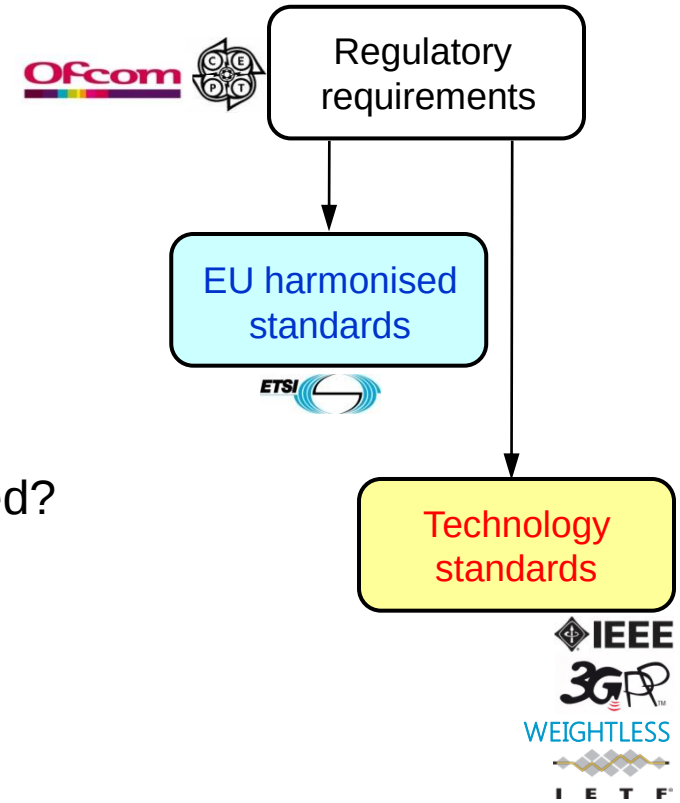
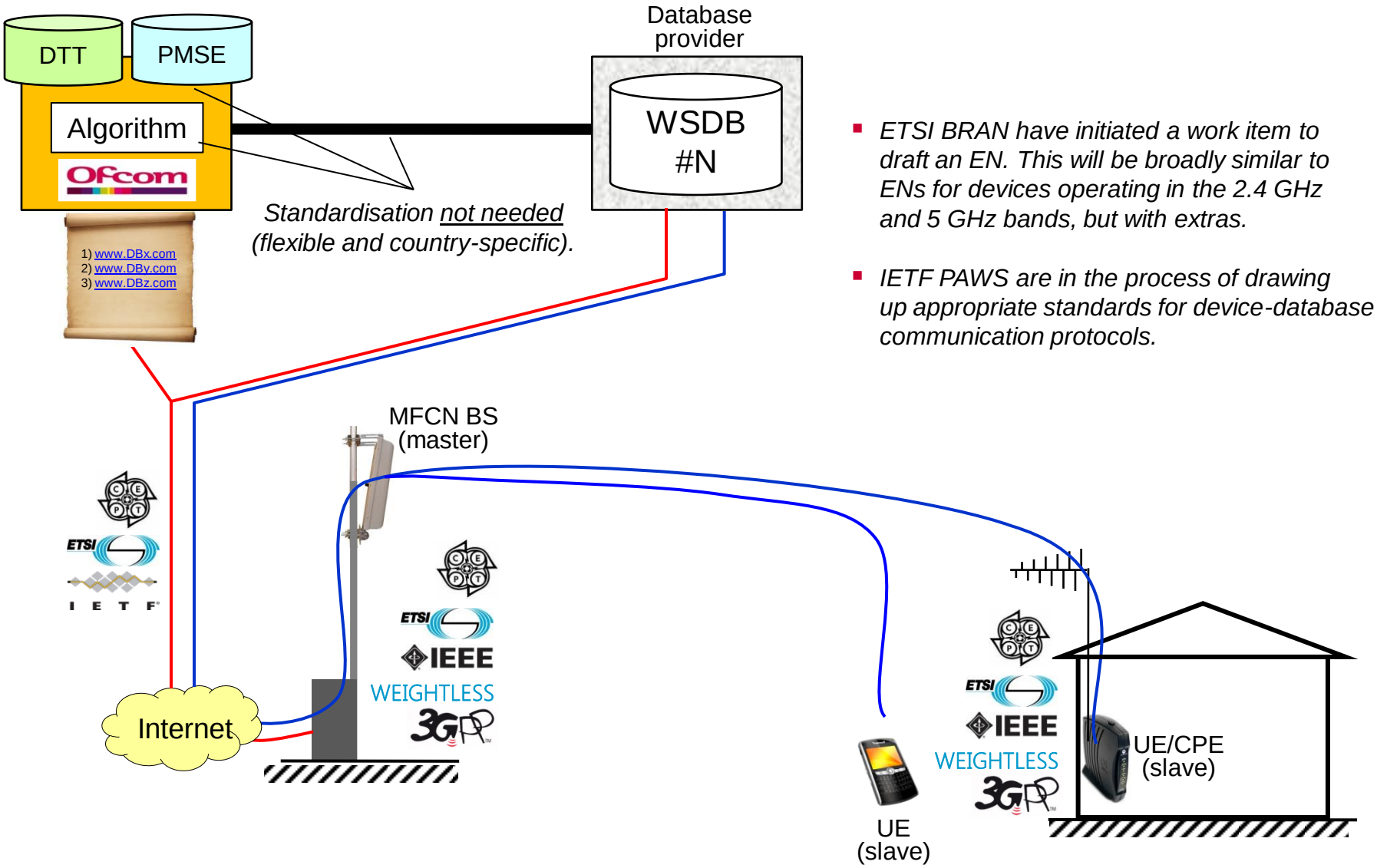
Standardisation is key



- Standardisation is important for three reasons:
  - To achieve economies of scale.
  - To allow for the roaming of WSDs across borders.
  - To enable a common European market.
- But what is it exactly that needs to be standardised?
- And where should these be standardised?
- Important to draw clear distinction between:
  - European harmonised standards
    Defined by organisations such as ETSI, required as a reference for compliance with the essential requirements of the R&TTE Directive, for placing products on the European market.
  - Technology standards
    Defined by organisations such as IEEE, 3GPP, Weightless SIG, IETF.

Standards and regulation: Summary



- *ETSI BRAN have initiated a work item to draft an EN. This will be broadly similar to ENs for devices operating in the 2.4 GHz and 5 GHz bands, but with extras.*
- *IETF PAWS are in the process of drawing up appropriate standards for device-database communication protocols.*

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- We have summarised the UK's framework for providing access to TV white spaces, and highlighted our approach for the protection of DTT and PMSE services.

- We believe that access to TV white spaces is an important test case

  - in enabling dynamic and opportunistic spectrum sharing, and
  - creating a framework for access to white spaces in other bands.

- The use of databases is a key enabling technology in the field of dynamic spectrum assess, to be complemented in due course with device-distributed cognitive and sensing technologies.

Thank you!

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