5CM510 – Network System development
Lecture 19:Network Slicing with Spectrum Sharing

UNIVERSITY OF DERBY

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Sensitivity: Internal

Lecture Outline

- The importance of Spectrum sharing
- Network Slicing
- Implementation of Network Slicing
- Enforcing Isolation
- A Real world Example (Ericsson)

Spectrum sharing

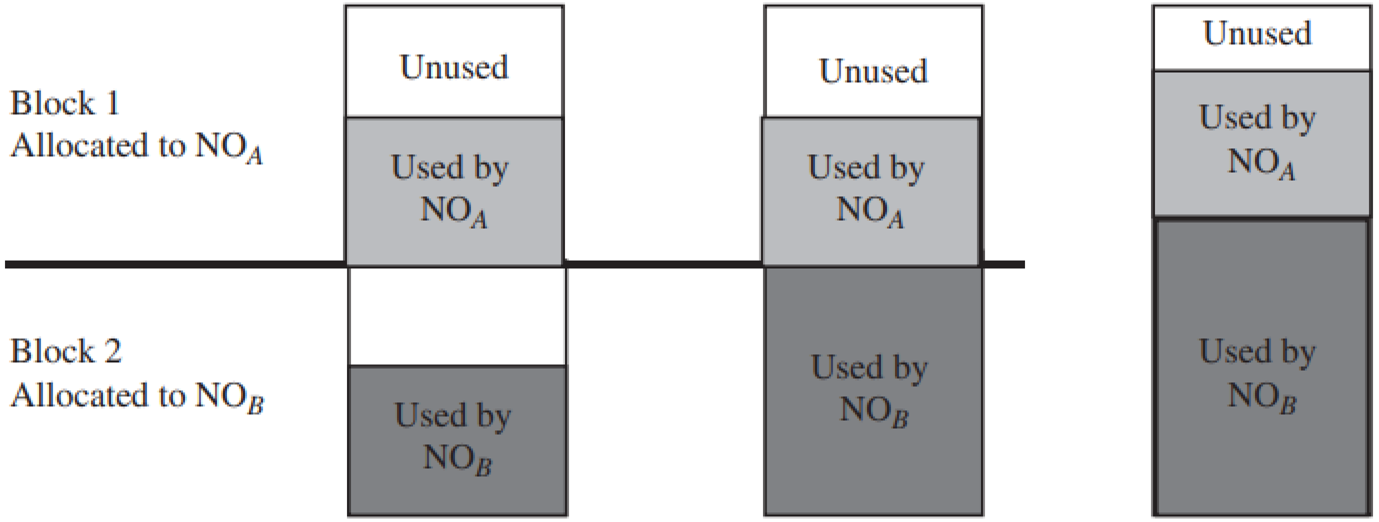
- Unlike fixed networks where resources can be easily expanded by installing more fibres, wireless networks are limited to a fixed amount of spectrum that is allocated to them.
- Blocks of spectrum are allocated to types of service by the International Telecommunication Union Radio Communication Sector (ITU-R) and those blocks are allocated, or subdivided and allocated, by national regulators.
- An example of the allocation (for the UK) is given in Office of Communications (Ofcom) - the UK’s communications regulator.
- Under the Wireless Telegraphy Act 2006 and the Communications Act 2003, Ofom has the statutory responsibility for allocating spectrum in conformity with the internationally agreed spectrum allocations of the International Telecommunication Union (ITU).
- With the increasing use of mobile devices there is greater demand on radio resources, and spectrum sharing is seen as an effective way to utilize the limited frequency resources available.
- Let us consider this scenario there are two network operators (NOA and NOB) that are allocated a certain amount of spectrum.

Class Quiz 1

Why can't we simply allocate more spectrum to solve the issue of network congestion?

What are potential risks or challenges associated with spectrum sharing?

Advantages of Spectrum sharing

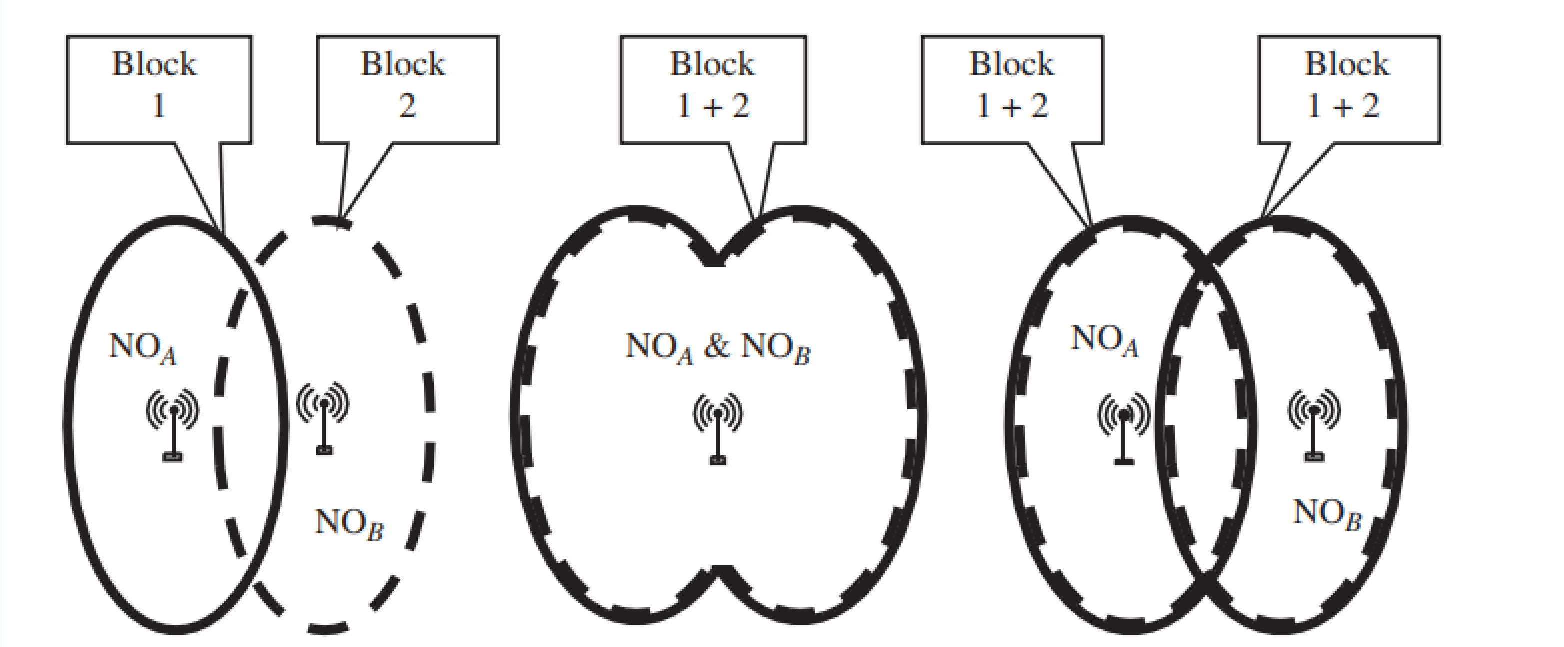


(a) No sharing – sufficient resource

(b) No sharing – NO_B has no spare resource

(c) Sharing

Spectrum and Transmission



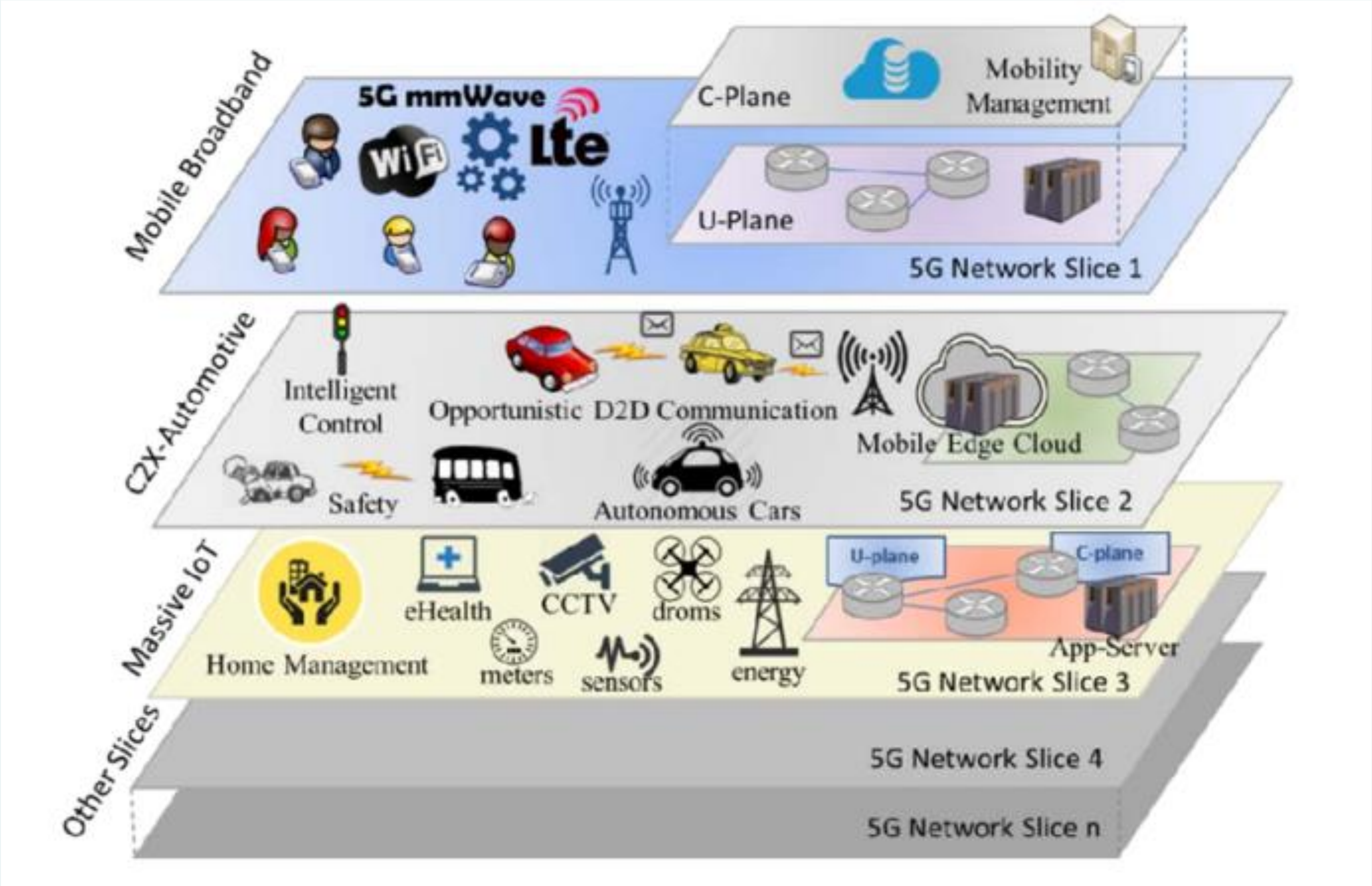
Complex form of sharing: Network slicing

- While explicit spectrum sharing allocates spectrum between operators, it takes no account of the impact of that sharing on the number of qualified users, and with uneven distributions this may lead to very unequal Qualified user ratios (QURs).
- On the other hand, implicit spectrum sharing, while concentrating on user priorities, does not consider the actual spectrum sharing at all.
- To balance fairness between spectrum allocation and users served, more complex forms of sharing are required.
- Where an explicit sharing ratio was used, but the allocation order was adjusted to give users with worse channel conditions a higher priority. This did achieve a better balance, but at the expense of overall throughput because users requiring more resource blocks (RBs) were being served before others requiring less.
- While giving priority to one particular operator would involve determining whether its users are predominantly edge or not, a simple serving order that just alternated between operators gave almost as much mitigation and did not need the user distribution to be determined.

Slicing: A new concept in 5G

- The main technique of the core network in 5G is called slicing, which means that a network forms a slice of an infrastructure. A slice is actually a virtual network. This way, the core network is a set of virtual networks sharing the same infrastructure. A slice may be:
- a network to connect objects: the Internet of Things;
- a network to control autonomous vehicles;
- a network to manage industrial processes;
- a type-MPLS network(multiprotocol label switching);
- a network for VoIP.
- A slice can cover other types of networks, for example:
- a network for each large application;
- a network for a large company;
- a network for a small company or a network per user, perhaps.

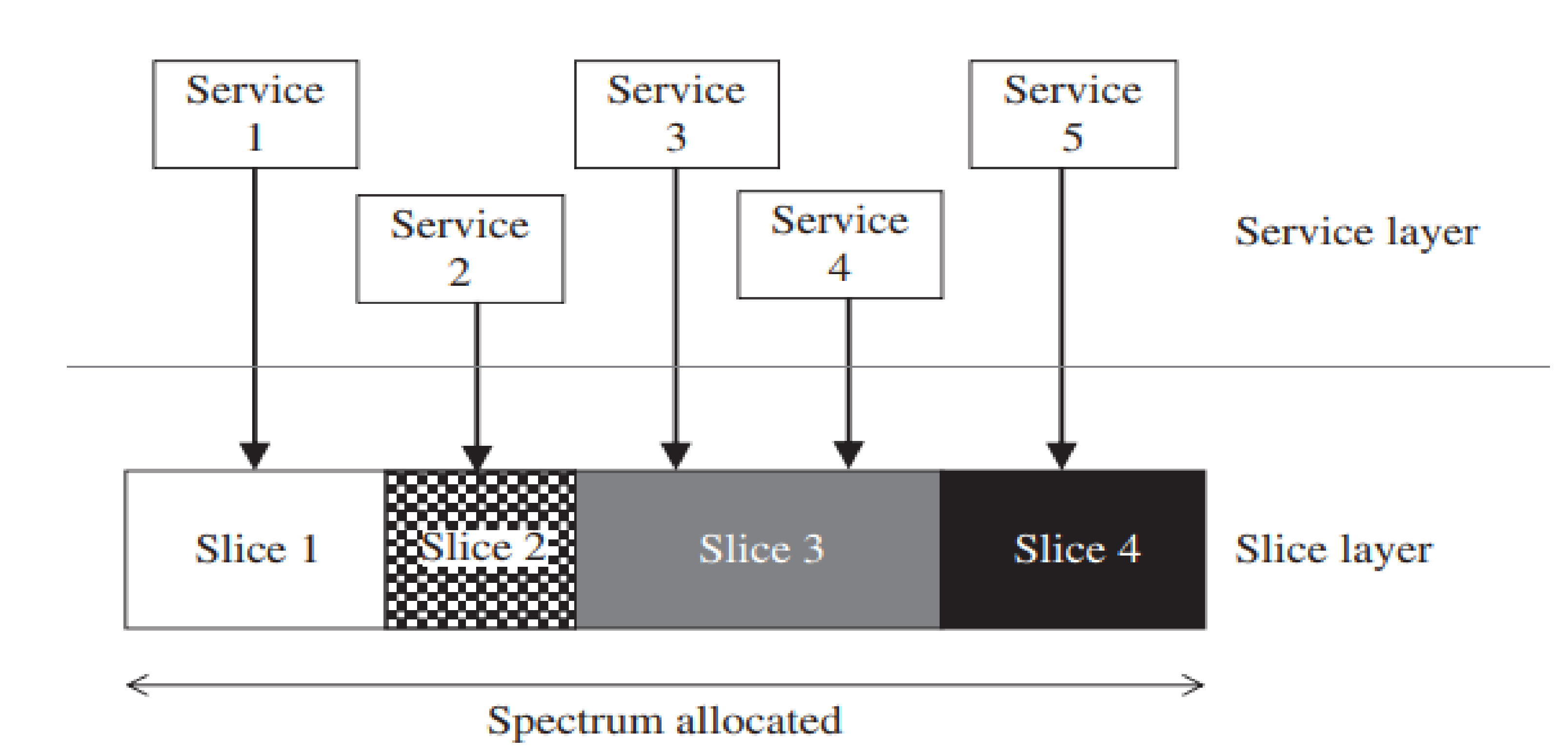
Basic Slicing of 5G core Network



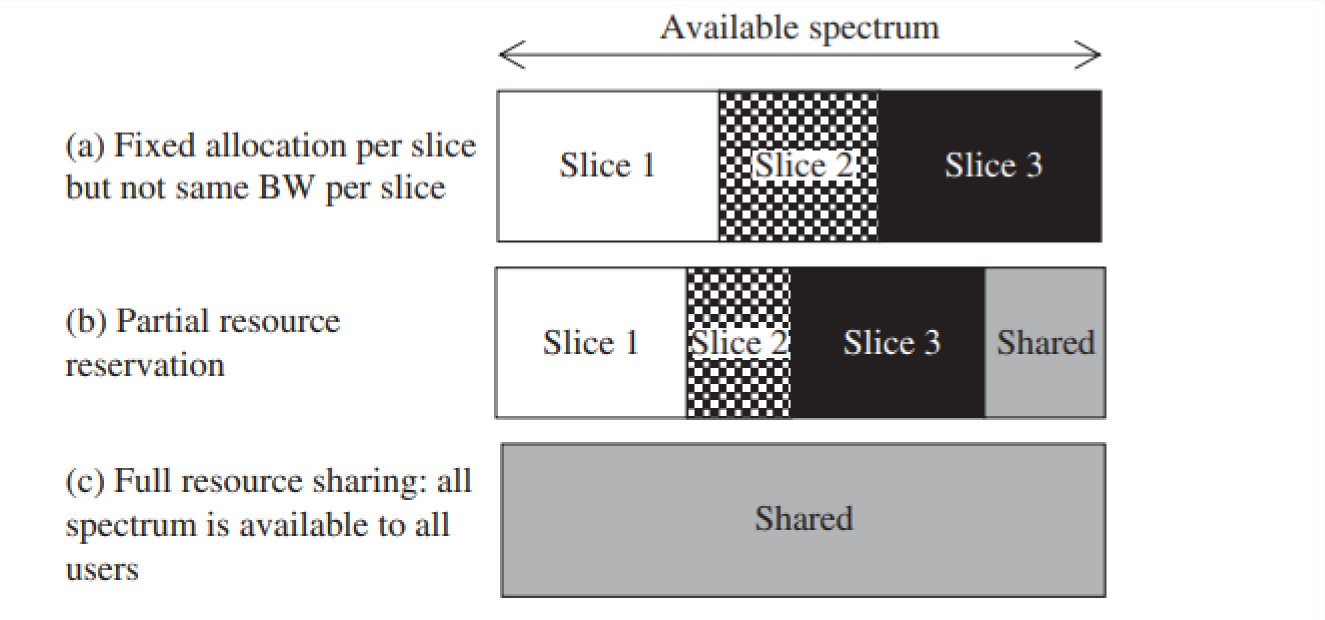
The Concept of Network Slicing

- With this concept the network is “sliced” logically into multiple virtual networks; each slice carries a particular service or group of services, and the concept is that the slice can manage the resources for users within that slice independently of the other slices.
- The slices can be used to divide the network between different operators or different services and in many ways follow the concept of virtual paths in asynchronous transfer mode (ATM) networks.
- Each slice can be optimized for a specific service or group of services, for example, to provide a certain minimum bitrate.
- Each slice has a certain set of attributes (for example, end to end low latency or high bandwidth) that can make it more appropriate for certain type of services.
- The slices can exist end-to-end (E2E) in the network or locally between points within the network.

Network Slicing: Conceptual View



Different ways to implement Network Slicing



Network slicing: Implementation

- **Static resource assignment:** A slice operates with a fixed resource. This provides a guaranteed resource allocation to the slices but does not allow for changing demand. ICI means that there can be intra-slice interference.
- **Partial resource reservation:** This is introduced by Guo and Arnott and combines a fixed allocation with a sharing region. The authors propose allocating a certain proportion of Bandwidth but in both these papers only a single cell is considered.
- A multi-cell problem models a uniform arrangement so that all cells have the same sharing arrangement. The partial resource reservation is an “in-between solution” and does require complex management. However, it can also be seen as a “mixed solution” where part of the available spectrum is guaranteed to each slice with the remainder being shared.
- **Full resource sharing:** In this model, all of the spectrum is available to users from any slice, but management of the sharing will allow users “belonging” to any slice to get the QoS they require. Previous work on spectrum sharing can be extended to network slicing, not only considering a multi-cell environment but also removing any restriction that slicing in each cell would be the same. Limits can be placed on the total amount of bandwidth available to each slice if needed.

End-to-End approach to Network Slicing

- Establishing a well-designed network slicing solution requires a comprehensive, end-to-end approach that integrates key functionalities across three critical layers according to Ericsson: monetization, automation and the network itself.
- By aligning these layers, a well-structured framework can deliver flexible, efficient and secure connectivity, tailored to the unique demands of diverse applications and industries.
- **The monetization layer** provides tools for managing contracts and service-level agreements (SLAs) with customers, partners and suppliers.
- **The automation layer** is essential for dynamic network slicing, enabling the rapid provisioning of slices, resource adjustments and network performance optimization to meet customer needs.
- **The network layer** is foundational for enabling end-to-end network slicing, and requires an integrated set of enablers in the three domains of the network: Radio Access Network (RAN), Transport, Core.

Network slicing in Action

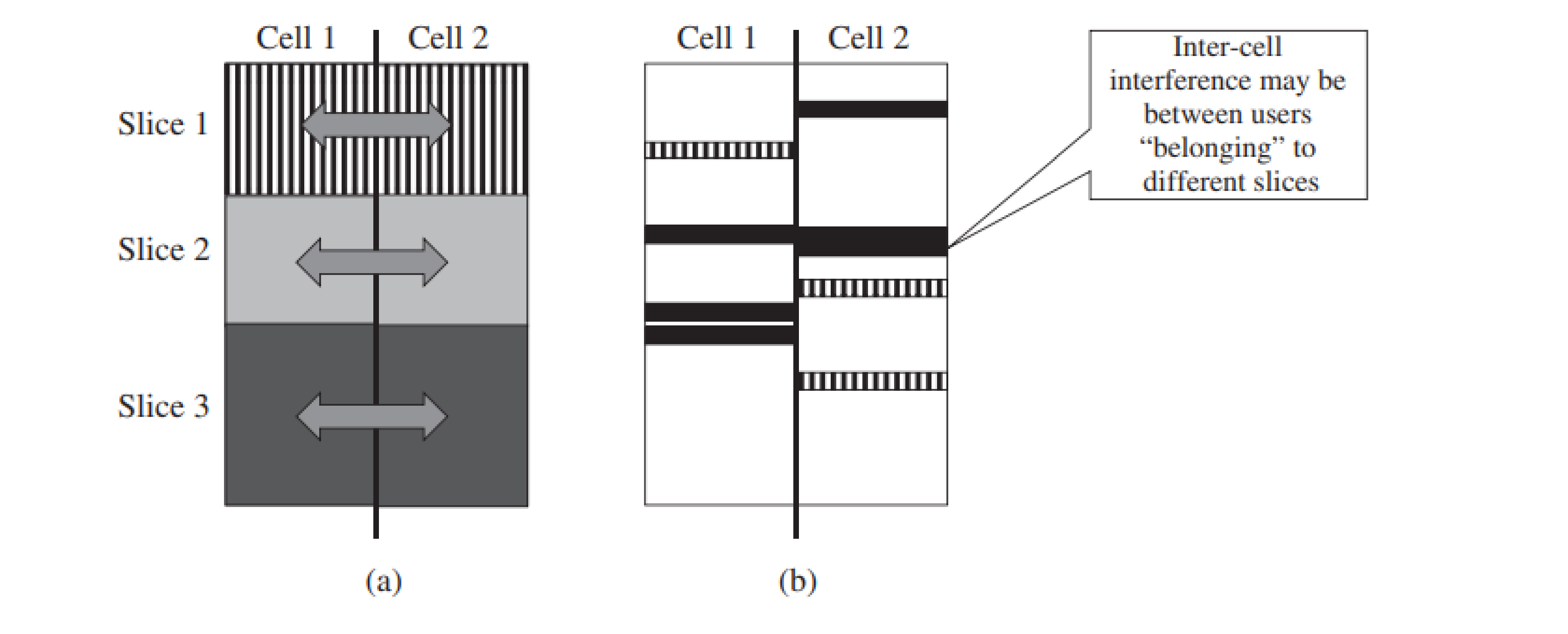
- Picture a major international sporting event, attended by thousands and watched live by millions across the world.
- A dedicated network slice – created specifically for broadcasting – provides ultra-high bandwidth, low latency and guaranteed reliability for streaming, allowing broadcasters to deliver seamless coverage.
- Journalists send high-definition videos from mobile devices, drones capture aerial footage and viewers enjoy smooth, delay-free content.
- The slice dynamically scales as demand increases, maintaining performance without interfering with network slices allocated to other services such as spectator engagement, security systems, public safety and other on-site connectivity requirements.

Class Quiz 2

Q: Why is isolation crucial in network slicing (as discussed), and what could happen if isolation fails?

Q: What strategies would you propose if significant inter-slice interference occurs?

Reduction in isolation between slices through inter-cell interference



Isolation

- Isolation is seen as the key in providing effective slicing and is defined as “The operator shall be able to operate different network slices in parallel with isolation that, for example, prevents one slice’s data communication to negatively impact services in other slices”.
- In the RAN, isolation is affected by interference. Unless a frequency resource factor≥1 is used, there will be co-channel inter-carrier interference (ICI) and, depending on the slicing structure, this may generate co-channel interference between slices.
- If the ICI reduces the signal to interference plus noise ratio (SINR) of an existing user to such an extent that can no longer meet its QoS requirements, then there is **no isolation**.
- It is necessary to consider the effect of ICI on the different resource allocation approaches.
- This can be exacerbated by movement of users (mobility) and changing channel conditions leading to changes in ICI.

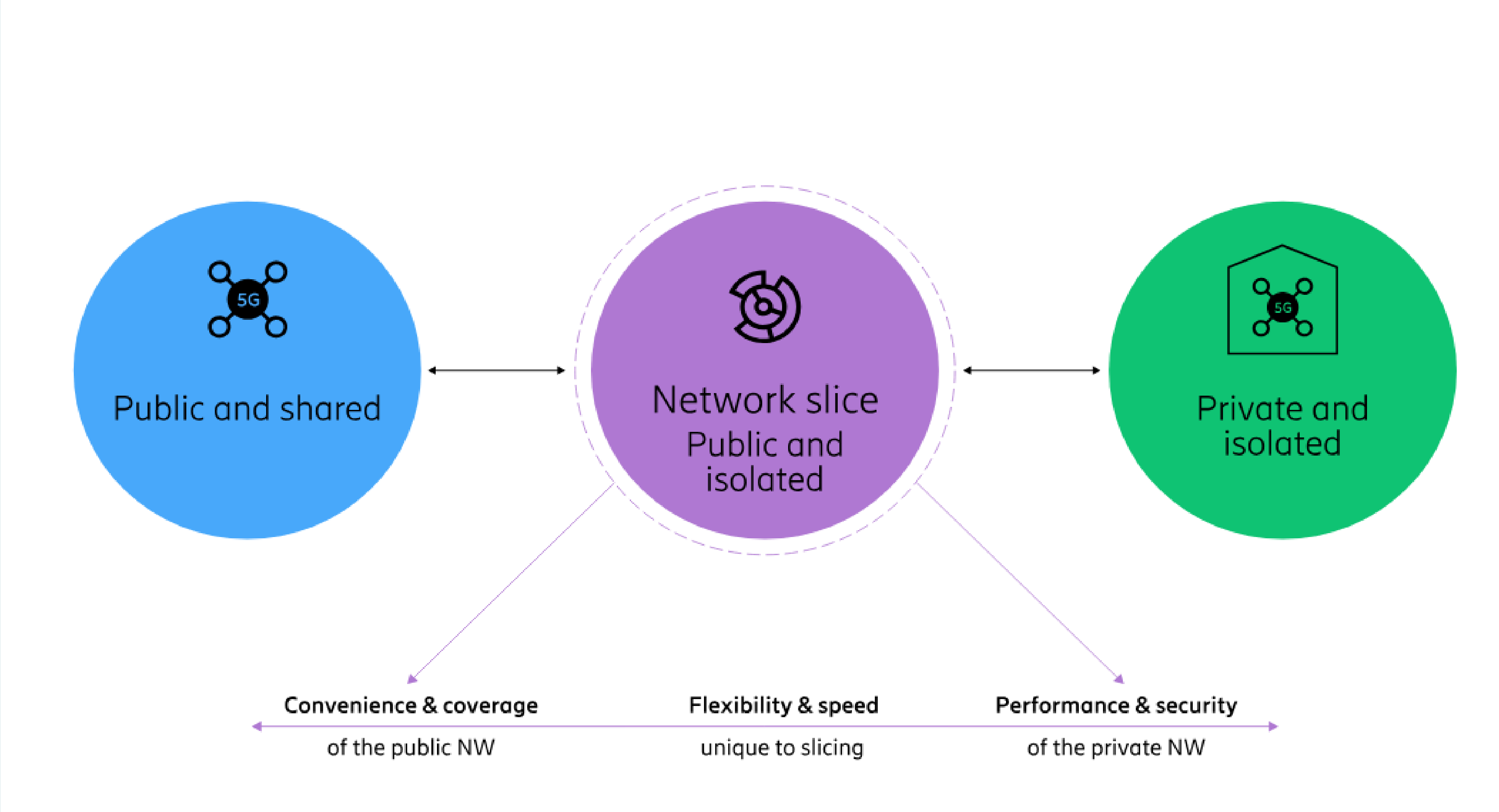
Isolation using connection admission control (CAC)

- the concept of implicit isolation has been around for a very long time in the form of connection admission control (CAC), which is indeed a control-plane function.
- CAC is applied whenever a new user request is received to determine whether sufficient resources can be made available to make the new user qualified without causing any of the existing users to become unqualified as a result of the extra interference.
- The scenario considered is the traditional “blocked calls cleared”: those users that are not qualified have their RBs released and the connections marked as rejected and not considered further.
- It would also be possible to set the scenario as “blocked calls queued”.

Isolation using CAC

- The basic steps of CAC are as follows, whenever a new user comes,
- Step 1: store the current RB allocation and co-channel interference map;
- Step 2: mark all existing qualified users (Qus) as PrUs (protected users);
- Step 3: use the game-theoretic approach to allocate resources to all the unqualified users (RB
- reallocation);
- Step 4: if the existing (protected) users have become unqualified, provide extra resources to those users to meet their desired SINRs (PrU compensation);
- Step 5: if one or more PrUs is still unqualified, loop back to step 3 until the result converges or the maximum number of iterations is reached, or all the users become qualified;
- Step6: In the end, if one or more PrUs still cannot meet the desired SINR, reject the new user and rollback to position at step 1 and end; if all PrUs are qualified, the new RB allocation will be recorded and the new user is accepted.

Network slicing :A blend of features in public and private Networks



Ericsson: What’s possible with Network Slicing

- Network slicing poses significant potential to **monetize 5G network investments** across both enterprise and consumer segments.

- The majority of related revenue will stem from industry sectors such as healthcare, government, transportation, energy and utilities, manufacturing and media and entertainment.

- Prioritized opportunities will depend on the communications service providers (CSP’s) enterprise strategy, and a natural starting point will be to assess existing customer relationships and local enterprise customers.

Points to note about Network Slicing

- A network slice provides a set of network capabilities and performance levels that may be suitable for a set of service types.
- A service must be mapped to at least one slice, but it may also be mapped to more than one slice.
- A network slice may be used by only one particular service type, or it may handle several types.
- The service type may represent more than just the normal concept of a service: for example, a mobile virtual network operator (MVNO) may be restricted to one or a limited set of slices by the physical network operator.
- Even where an “end-to-end” network slice is required, the concept of horizontal vs. vertical network slicing will also be important.
- vertical slices can be used to serve different needs within a particular vertical, horizontal slices can be created support similar classes of devices, which could then be used to serve end users in multiple verticals.

Real-World Example

- Context:
- Ericsson’s solution involves a suite of software and management tools that enable operators to offer customized network slices optimized for specific use cases such as industrial IoT, autonomous vehicles, or augmented reality.
- Features:
    - End-to-end slice orchestration across radio, core, and transport networks.
    - Automation leveraging AI and machine learning for proactive management.
    - Real-time monitoring and dynamic adjustment of resources based on demand and QoS requirements.
- Real-world Application:
- In Germany, **Ericsson collaborated with Deutsche Telekom** to create dedicated network slices for smart factories, providing precise QoS guarantees. This enabled secure, isolated communications critical for automated production lines and robotics, significantly enhancing operational efficiency and reliability.


UNIVERSITY OF DERBY
University of Derby, Kedleston Road, Derby, DE22 1GB
T +44 (0)1332 591044 E opendays@derby.ac.uk
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derby.ac.uk