Licensed Shared Access to spectrum

Business and technology perspectives

The Italian Pilot on the Licensed Shared Access in the 2.3-2.4 GHz band
Presentation of the results
Rome, 23 September 2016

seppo.yrjola@nokia.com
Nokia Innovation Steering

Outline

Future of spectrum
LSA business enablers
LSA technology enablers
Explosion of possibilities

- **AUGMENTED**
- **REDEDICATED**
- **AUTONOMOUS**

- **INTERCONNECTED**
- **VIRTUAL**
- **TACTILE**
- **SUPEREFFICIENT**

---

**Spectrum as a market gatekeeper**

- Limited low frequency spectrum a key deal driver
- Novel wholesale spectrum market established
- Mobile operators competing for access to bands such as mm-wave
- Lobbying efforts for alternative spectrum access by potential new entrants

**Spectrum shapes the entire communications industry**
Growth in demand for spectrum shows no sign of abating

Even today demand threatens to outstrip supply. Yet, 110x more mobile traffic by 2026.

Dimensions for scaling wireless capacity to address capacity crunch

Without additional sources of spectrum, only 40x of capacity gain still available
Securing additional licensed spectrum is challenging
Increasing delays in making harmonized spectrum available for mobile broadband

Total spectrum identified globally for mobile communications

Source: ITU

Commercial mobile competes with other industries and applications for spectrum

Diversified business environments and spaces

Site/premises owner role can be emphasized in building, operating and maintaining local content and services related to connectivity
How does densification help to double capacity?

Sparse networks

To double capacity in dense networks requires a lot of densification or doubling of spectrum

Value of spectrum increases for dense cells

New roles emerging in the ecosystem

Importance of content, context and commerce based business models
Critical factors shaping future business models

Three new approaches to sourcing much-needed spectrum:
- Managed shared spectrum (LSA, CBRS)
- Higher frequency bands (cmWave, mmWave)
- Blending of unlicensed and licensed bands

Emerging new scenario: managed shared spectrum model
- New routes to low-cost spectrum
- New, web-scale, spectrum brokers
- New dynamic business models for wireless communications

Changing market landscape and players
- Fragmentation and new competition in operator business
- Emerging local micro-operators
- New opportunities with spectrum management and brokering

World 1st LSA Pilot field trial in Rome proved applicability of existing technologies

The latest CEPT & ETSI standards with Nokia iSON LSA Demo Controller, FZ radios and OAM
LSA and network’s Operation, Administration and Management (OAM)
3GPP SA5 study TR 32.855

LSA controller is part of the OAM. LSA controller performs the configuration decisions (some or all) internally and communicates actual configuration attributes (TX power, antenna downtilt, etc...) to the corresponding functional blocks.

LSA leverages existing OAM and Self-Organizing Network (SON) processes
LC implementation steps and evacuation modes in the operational phase

Emergency Plan
- Deactivation of all LSA cells
- Minimum Separation Distance (MSD)
- Protection Zone Optimization (PZO)
- Power Control (PWR) Beam steering

Emergency plan speeds up large scale LSA spectrum evacuation
NetAct LTE OAM radio configurator performance test results for typical network configuration

<table>
<thead>
<tr>
<th>1 eNB HD</th>
<th>Configuration used in testing</th>
<th>Objects in one eNB</th>
<th>Cells in one eNB</th>
<th>GM5s</th>
<th>eNBs below one OMS</th>
<th>Total eNBs</th>
<th>Total cells</th>
<th>Total objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMTS</td>
<td>CM only and System Level PET</td>
<td>5432</td>
<td>12</td>
<td>4</td>
<td>1000</td>
<td>4000</td>
<td>48000</td>
<td>21.7 million</td>
</tr>
<tr>
<td>NMB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NML</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LNB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Test case
- Configuration plan file download for a single eNB: < 1 min
- Emergency plan download with automatic activation operation for the whole network with small amount of online modifiable parameters (e.g. access class barring case, LSA): < 3 min

Network wide emergency plan in less than 3 minutes
Minimum Separation Distance (MSD)

The required distance between interfering transmitter and victim receiver

Required path loss can be translated into a separation distance between interfering transmitter and victim receiver. For this purpose, the Modified Hata Propagation (MHD) model (ERC 068, 2002) was used under the assumption of the propagation environment given for ECC 172 (2012) scenarios.

Protection zone optimization maximizes the number of transmitting BSs

Protection Zone Optimization (PZO) method computes the aggregated interference and takes into account the interference impact of the network holistically compared to MSD computation of individual base stations.
**LSA field Trial#6** run system end-to-end performance evaluation in May 2015

With Self Organized Network iSON LSA Controller and novel protection algorithms

---

**Table 1. LSA band evacuation measurement results**

<table>
<thead>
<tr>
<th>Event point</th>
<th>Evacuation MSD</th>
<th>Evacuation PZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Licensed shared access (LSA)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. OAM starts de-activation command</td>
<td>0.27</td>
<td>0.07</td>
</tr>
<tr>
<td>3. OAM starts de-activation command</td>
<td>1.17</td>
<td>0.75</td>
</tr>
<tr>
<td>4. OAM ends LSA band de-activation</td>
<td>2.13</td>
<td>2.13</td>
</tr>
</tbody>
</table>

**Table 2. Total measured evacuation times of each trial system element**

<table>
<thead>
<tr>
<th>Total measured evacuation times (s)</th>
<th>MSD</th>
<th>PZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMS</td>
<td>5.01</td>
<td>5.01</td>
</tr>
<tr>
<td>LC</td>
<td>3.93</td>
<td>3.93</td>
</tr>
<tr>
<td>ER</td>
<td>3.01</td>
<td>3.04</td>
</tr>
<tr>
<td>Algorithm calculation</td>
<td>0.58</td>
<td>0.50</td>
</tr>
</tbody>
</table>

On average LSA band was cleared in 24 seconds.

---

**Power control algorithm maximizes the LSA capacity**

---

SON LSA Controller’s objective is to maximize the average received signal power in the MNO network (outside the PZ) given the constraint on the allowed interference level in the incumbent protection zone, and the constraints on the feasible values of the transmit power levels.

---


Restriction Zone (RZ) with power control

1. The transmit power of the BS is restricted to the value of the pixel.
2. A full signal strength prediction is performed to the MNO network using the transmission power levels restricted by RZ.
3. The obtained prediction data is used in LC optimization algorithms along with the Incumbent PZ characteristics to achieve an optimal transmit configuration in the MNO network. When using combined PZO algorithm and RZ protection dynamically, RZ defines, which base stations can be used in the network.

Example of EIRP constraints on the mobile service developed under the restriction/exclusion zone concept. EIRP restrictions become more stringent towards red color pixels (100x100m2).

BS interference dominates in TDD networks

When mobile network is operated in TDD mode, both BS and UE transmit on the same frequency. Due to higher antennal location and higher transmission power, interference from base station is higher than interference from user equipment.

Due to this effect, it is possible to simplify interference analysis of a mobile cell by computing the interference of the base station only in TDD case.
LTE-A features and SON functions automate and optimize LSA operations

<table>
<thead>
<tr>
<th>Process</th>
<th>LSA workflow</th>
<th>Technology enablers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharing framework &amp;</td>
<td>Enter and store sharing framework, sharing agreement and spectrum license</td>
<td>Nominal network radio planning (Network dimensioning for the business case)</td>
</tr>
<tr>
<td>licensing</td>
<td>information, report to OAM</td>
<td></td>
</tr>
<tr>
<td>Network planning &amp;</td>
<td>Receive incumbents usage &amp; protection requirements; Identify, configure and</td>
<td>Predictive operations with detailed network planning, SON Heterogeneous Network</td>
</tr>
<tr>
<td>configuration</td>
<td>optimize BSs for LSA spectrum.</td>
<td>self-configuration and optimization</td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activation</td>
<td>BS radio activation and configuration, interference estimation and reporting</td>
<td>SON HetNet self-configuration and optimization, Network measurements (opt.)</td>
</tr>
<tr>
<td></td>
<td>on LSA spectrum usage</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Optimize LSA resource usage, interference estimation, maintain QoS and QoE</td>
<td>Re-selection, Handovers, Load Balancing, Carrier Aggregation, Active Antenna System,</td>
</tr>
<tr>
<td>De-activation</td>
<td>BS radio de-activation, interference estimation, maintain QoS and QoE,</td>
<td>QoE based Traffic Steering</td>
</tr>
<tr>
<td></td>
<td>confirm resource usage</td>
<td></td>
</tr>
</tbody>
</table>

How to avoid the interference without locking the cell?

- Reduced Tx power
- Nominal Tx power
- Base Station TX power optimization
- Antenna Tilt control / Beam Steering

FutureWorks
How to avoid radio link failures when locking cells?

In the **Graceful Shutdown** Tx power is reduced stepwise during a certain period. This allows users to be handed over to other cells, reducing the number of RLFs when these cells are locked with Hard Shutdown.

---

FDD – TDD Carrier Aggregation boosts mean and peak downlink user throughput
More efficient spectrum usage due to soft load balancing between FDD and TDD carriers

Boost mean and peak downlink user throughput via allowing for aggregation of component carriers working in FDD and TDD duplex modes
User experience enhancement with TDD-FDD Aggregation
Coverage and capacity

TDD-FDD aggregation for coverage:
• Uplink uses lower FDD carrier for coverage
• Downlink uses TDD and FDD carriers for high data rates

Load Balancing optimizes infrastructure utilization & end user experience
Interworking and mobility functionality examples

Idle Mode Mobility
Dedicated priorities enable for certain percentage of the terminals to smoothly reselect the other freq. layer during call release.

Inter frequency load balancing
UE can be offloaded via Inter Frequency Handover (iFHQ) to cell that belongs to the same or neighbor eNB

Impact on operational KPIs
Improved distribution of UEs on different layers
Superb capability to manager special events with high traffic density

Effective capacity gains with load-balancing

Statistical distribution of UEs towards different frequency layers and RATs
Traffic steering distributes traffic and customers across the HetNet to increase network capacity and maximize performance for high value traffic.

**Insight**
- Customer experience
- Service performance
- Network performance
- Traffic patterns

**Action**

**Result**

FutureWorks

### LSA evolution scenarios towards dynamic use cases
Evolution from static LSA to dynamic LSA (including spectrum pools for Small Cells)

**Dynamic Spectrum sharing support for LSA:**
- Dynamic spectrum control by Incumbent
- Policies for dynamic sharing via a spectrum pool
- Adaptation of protocol between LSA Controller and LSA Repository

**Spectrum Management Function**
- Extent defined interfaces, protocols & data model (re-use)
- Flexibility in adding spectrum management function to the LSA network (Repository or independent Network Entity)
- Allow new roles for LSA (e.g. Spectrum Manager)
**Licensed Shared Access to spectrum**

- Traffic grows faster than new traditional exclusive spectrum is coming available
- LSA allows for sharing while meeting the requirements of mobile operators and incumbents for predictable conditions of spectrum use and QoS.
- LSA opens bands otherwise locked for long time for harmonized MBB use like the 2.3 GHz and 3.5 GHz bands supported in commercial radios today.
- LSA is a simple concept which can be implemented today with evolution path towards dynamic use cases like spectrum pooling and the US 3 tier CBRS concept.
- The LSA pilot has proven above aspects testified by all stakeholders including regulator, incumbent, mobile operator and supplying industry.
- LSA lowers entry barrier and paves way to new business model designs
- 5G will only be possible with intelligent spectrum sharing.
Thank you.
Questions/discussion?
seppo.yrjola@nokia.com