Concept to maximize the benefit of interference rejection at the UE receiver:
Interference Suppression Subframes (ISS)

Broadcom Corporation

3GPP TSG-RAN Workshop on Release 12 and onwards

Ljubljana, Slovenia, June 11—12, 2012

RWS-120051

LTE Release 10 & Beyond

- Specification for LTE-Advanced was initiated in Release 10 with requirements for peak and average spectrum efficiency, and cell-edge user throughput

Parameter	Downlink	Uplink
Maximum Bandwidth	Up to 100 MHz	
Peak data rate (Mbps)	1000	500
Peak spectral efficiency (bps/Hz)	30	15
Average spectral efficiency (bps/Hz/Cell)	2.4 for 2x2 2.6 for 4x2 3.7 for 4x4	1.2 for 1x2 2 for 2x4
Cell-edge user spectral efficiency (bps/Hz)	0.07 for 2x2 0.09 for 4x2 0.12 for 4x4	0.04 for 1x2 0.07 for 2x4
VoIP capacity (user/cell/MHz)	Exceeding LTE Release 8	
User plane latency (ms)	10	
Control plane latency (ms)	50 (Idle to Active) 10 (Dormant to Active)	
Mobility	350km/h	

BROADCOM

LTE-Advanced Techniques

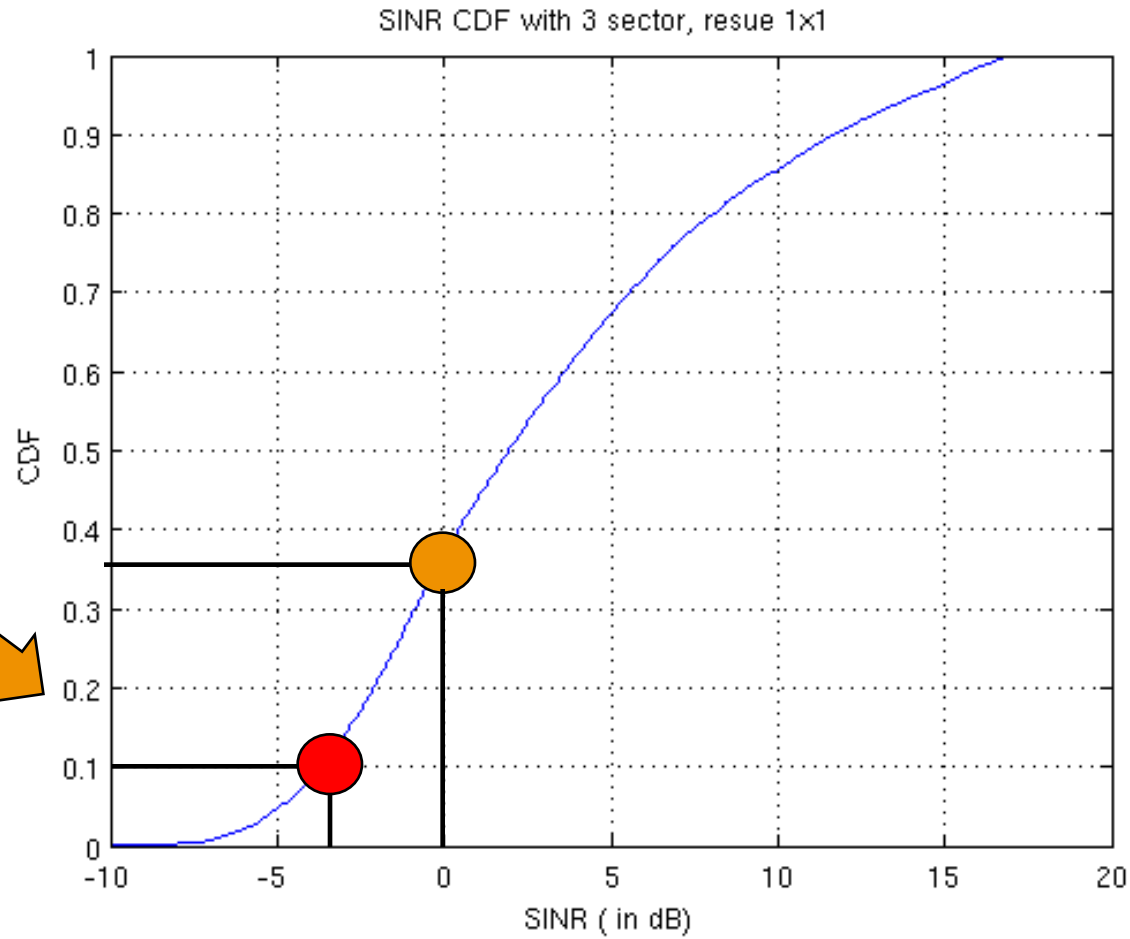
- **Carrier Aggregation**
- **Enhanced Inter-Cell Interference Coordination (eICIC)**
- **Advanced multi-antenna transmission techniques**
  - higher-order single user (SU)-MIMO,
  - multi-user (MU)-MIMO,
  - coordinated multipoint (CoMP) transmission/reception,
  - interference rejection combining (IRC) receiver
- **These techniques work collectively to achieve the promised spectral efficiencies in Release-10**

SINR Distribution Multi-Cell Network

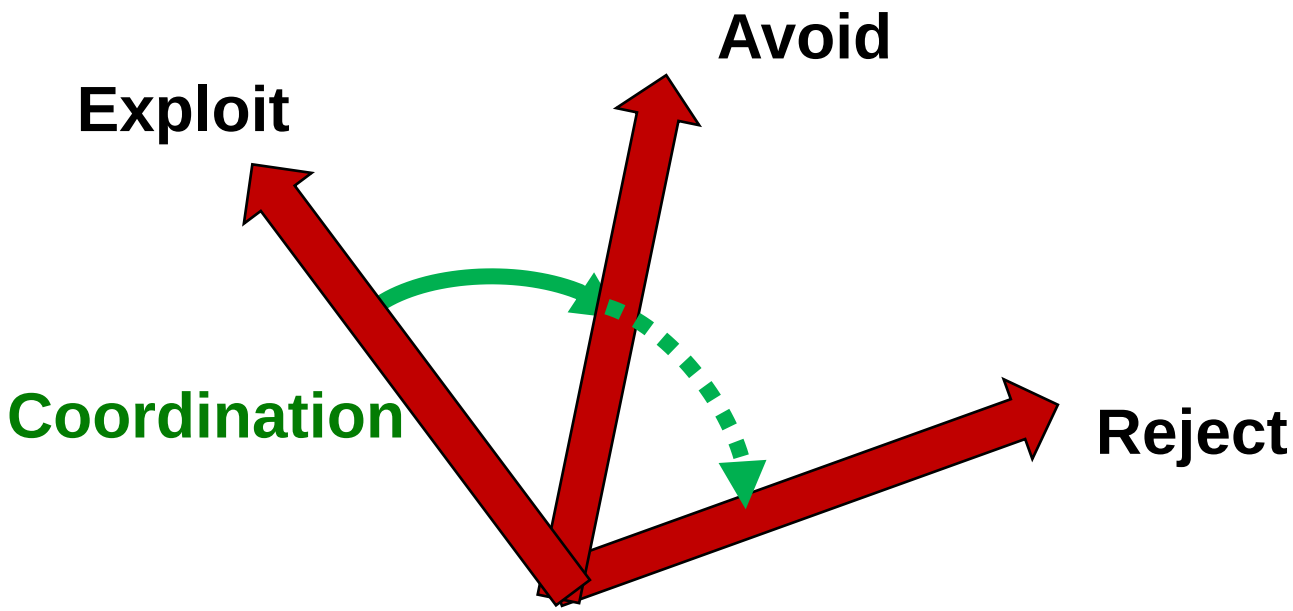
- **Cell-edge user SINR remains to be the "Achilles' heel"**

10% <= -4dB

35% <= 0dB



Interference: “The Final Frontier”



Handling Interference in LTE-Advanced

- **Two types of approaches:**
  - Transmitter-based techniques
  - Receiver-based techniques
- **Transmitter-based techniques (eNB)**
  - eICIC
  - Almost Blank Subframe (ABS)
    - “Coordinated” interference “avoidance” among multiple transmitters
  - Coordinated multi-point (CoMP)
- **Receiver-based techniques (UE)**
  - Multiple antenna enables Interference suppression
  - Interference Rejection Combining (IRC) receiver

IRC Receiver

- **Multi-cell interference is undoubtedly the major limiting factor in full-coverage broadband wireless access networks**
  - Mitigating its effect onto the downlink data transmission is a key challenge in future wireless communication systems
- **Transmitter-based techniques (eICIC) and Receiver-based techniques (IRC) can work independently. However, when working together result in significant reduction in the overall interference and improvement to system performance**

IRC Receiver

- **IRC: Initially discussed in RAN1 and currently the minimum requirements for this receiver are defined in RAN4**
- **IRC is effective in improving cell-edge user T-put**
  - It suppresses inter-cell interference
- **IRC receivers are better than baseline MRC receiver**
  - IRC receivers require the knowledge of interference signals (or statistics)
    - Interference signal covariance matrix in addition to the desired signal

	Throughput (Mbps)*		
RAN-4 Scenario	**Baseline**	**MMSE-IRC**	**Gain (%)**
1 (TM2-TM3)	2.3	2.8	**19.6**
2 (TM6-TM4)	3.8	4.8	**26.1**
3 (TM9-TM9)	3.6	4.3	**21.8**

G=-2.5dB, Mod=16-QAM, MCS=8, Channel=EVA5, 2 Synchronous interferers

***Source: R4-123033, Summary of link level performance evaluation, Renesas**

IRC Receiver

- **RAN-4 evaluations define minimum performance requirements**
  - Assumptions are made Synchronous cells, TMs pairing, etc
- **IRC applicability in MIMO-OFDMA systems is not fully understood**
- **Performance improvements from IRC need to take into account:**
  - Channel estimation errors
  - Interference signal covariance matrix estimation errors
  - Limited averaging within PRB when pre-coding is used

Interference Estimation (1)

- **LTE standard defines several different transmission modes (TMs) configured on a per user basis**
  - Modes TM1 and TM2 apply the same complex transmission weight on data and cell specific pilots on per transmit port basis
  - Modes TM4 and TM6 include pre-coding of data tones with PRB and user specific pre-coder matrix of a given rank
  - Mode TM3 circulates a fixed set of predefined pre-coders of a given rank across data tones within given user allocation
  - Modes TM5, TM7, TM8 and TM9, apply beamforming of a given rank to both data and user specific pilot tones within given user allocation
- **Due to Cell-ID specific shift of pilot tone positions, pilot (data) tones of serving eNB may or may not overlap with pilot (data) tones of interfering eNB**
  - eNBs are not required to be synchronized, hence interference measured on pilots may include contribution of both pilot and data tones of interfering eNBs

Interference Estimation (2)

- **Due to dynamic scheduling on per sub-frame and per PRB basis, it is difficult for UE to reliably determine for any given sub-frame and PRB if the interference suppression process should be enabled or disabled**
  - Applying interference suppression for undesired combination of TMs can lead to performance degradation as compared to non-interference suppression processing
  - Current test cases for interference suppression capability in RAN4 has conveniently avoided those undesired TM combinations
- **Few combinations of TMs of interfered and interfering users allow for meaningful interference suppression processing at the interfered user receiver**

IRC Performance

- **RAN4 link level results show that performance gains from IRC are marginal in some scenarios**

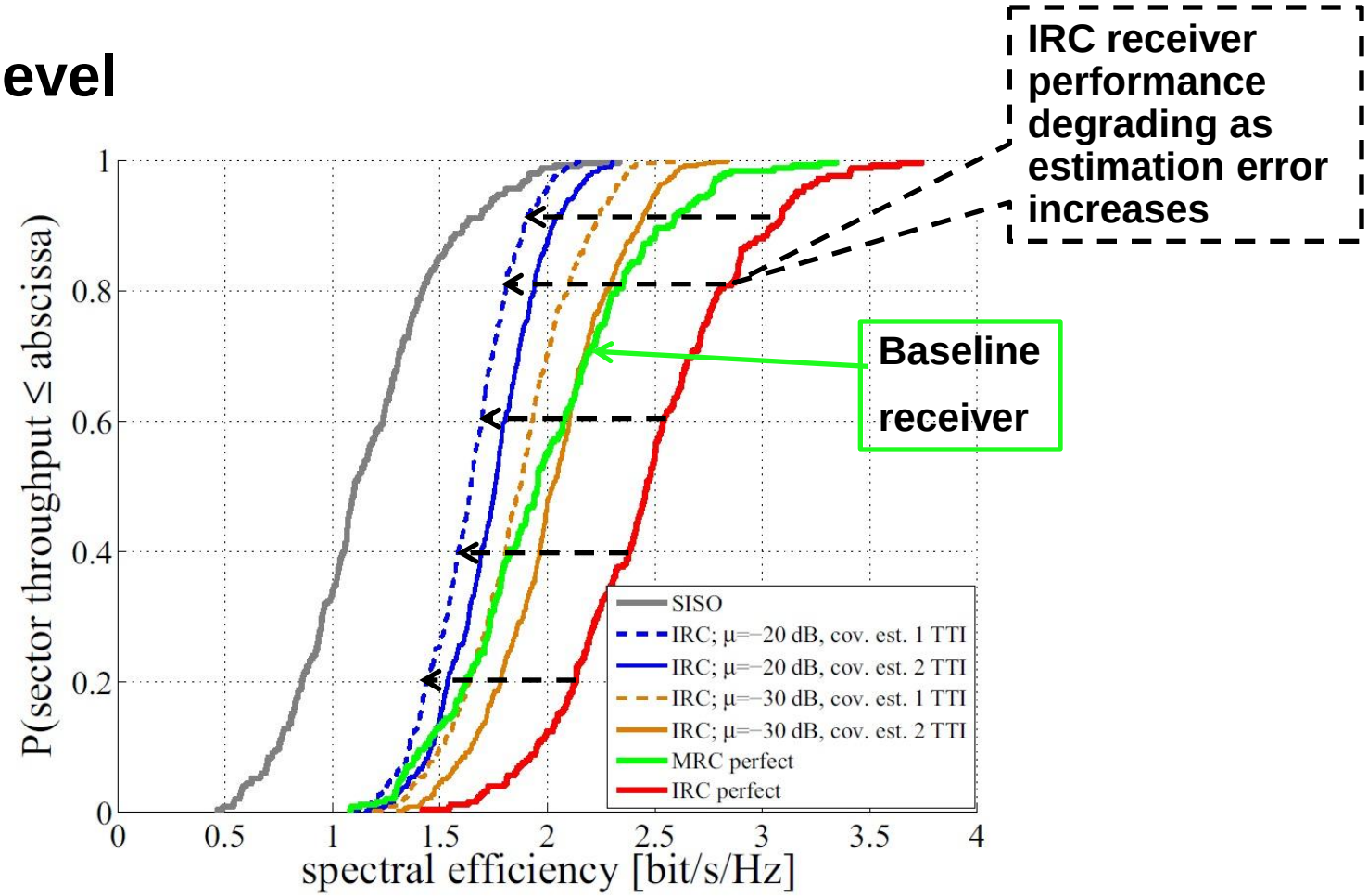
		Throughput (Mbps) *		
G (dB)	**MCS**	**Baseline**	**MMSE-IRC**	**Gain (%)**
-2.5	7	1.880	2.070	**10.20%**
0	10	2.560	2.730	**6.80%**
-2.5	7	1.980	2.050	**3.70%**
0	10	2.690	2.750	**2.30%**

EVA70, 16QAM, Scenario 1 (TM2-TM3), 1 Synchronous interferers

***Source: R4-123033, Summary of link level performance evaluation, Renesas**

IRC Performance

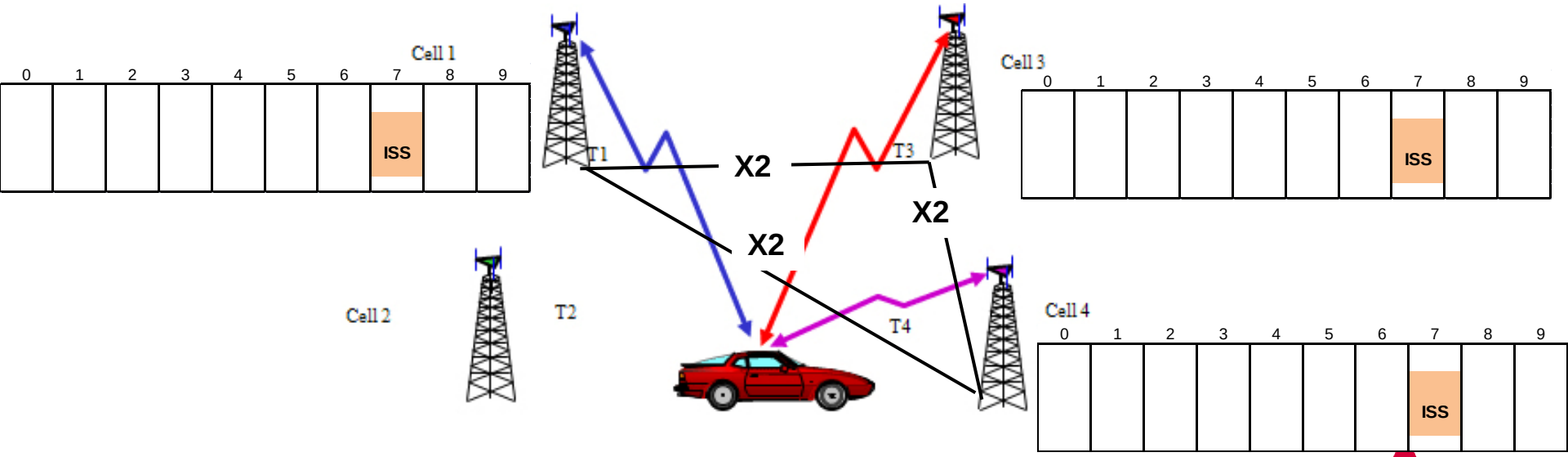
- **System Level**



Y. Ohwatari et al, "Performance of Advanced Receiver Employing Interference Rejection Combining to Suppress Inter-Cell Interference in LTE-Advanced Downlink", Proc. IEEE Veh. Tech. Conf. Fall 2011.

Interference Suppression Subframes

- **ISS allows users from different eNBs in the same geographical region to be scheduled with favorable TM combinations and/or subject to additional conditions which allow UE to reliably apply interference suppression processing**
- **The information about interference suppression subframes (ISS) can be broadcasted from a serving eNB in the form of a bit map**



What's Next?

- **IRC performance is enhanced by additional coordination between eNBs through concept of ISS**
- **Propose to add ISS (as network coordinated/assisted techniques) as a study item in Release 12**
- **SI includes several involvements from RAN groups**
  - RAN 1 to further evaluate the improvements from ISS
    - Examine impacts of delays, measurement bandwidths, errors etc
  - RAN 2 to further develop the signaling and message structure
  - RAN 4 to develop more test cases and minimum performance specifications