

insert affiliates

Parameter	Assumption
Carrier frequency	2000 MHz
Number of eNodeB cell sites	19
Number of cells per eNodeB	3, total (57 cells)
Inter-site distance	0.5Km
Cell layout	Hexagonal grid with wrap-around
Path loss model	$L = 128.1 + 37.6 \log_{10}(R)$ , R is user distance from BS, in Km
Penetration loss	10 dB
Lognormal shadowing	Log Normal Fading with 10 dB standard deviation
UE distribution	Uniform density
Maximum BS TX power	46dBm
Maximum UE TX power	23dBm
Minimum UE TX power	-30dBm
Antenna gain after cable loss	15 dBi
UE Antenna gain	0 dBi
White noise power density	-174 dBm/Hz
BS noise figure	5 dB
UE noise figure	9 dB

where BLER is the block error probability that depends on the SINR of user  $u$ ,  $D_u$  is its data block payload in bits, and TTI is the transmission time interval.

#### A. Experimental scenarios and results

### V. CONCLUSION

In this paper, we introduced a common solution for automated fault detection and diagnosis called ARCA.

The research was motivated by our finding that due to continuous increase in size and complexity, modern cellular networks are more prone to errors than ever before resulting in the current manual detection and diagnosis procedure performed during RCA becoming too slow, expensive and no longer practical.

ARCA uses Naive Bayes probabilistic classifier together with the EM algorithm to offer a simple and adaptive solution for automatic root cause analysis suitable for self-healing emerging cellular networks based on SON such as LTE-A and 5G.

Its main benefits include:

- Continuous and adaptive learning which increases RCA accuracy and expert knowledge reuse and improvement.
- ability to work with missing and uncertain data
- High performance and accuracy with large even with large datasets

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TABLE II. ALGORITHM PARAMETERS

Parameter	Operator Policy A	Operator Policy B	Parameter Description
Scope	57 cells	10 cells	Number of cells in test area
Exclusion scope	[ ]	[ ]	Ids of cells excluded from analysis
Schedule	Start now	Closed loop	Schedule
Action scope name prefix	ARCA_MAN	ARCA_CLOP	RCA output scope name prefix
Cure trigger strategy	Manual	Automatic	Mode of triggering SH SON functions
Data statistical validity	2 weeks	2 weeks	Minimum period of gathering network measurements
KPI summarization	Last hour	Last 15min	Measurement frequency
KPI Thresholds			Expert defined thresholds
RSRP [dBm]	-117	-117	Minimum signal strength required to get LTE service
RSRQ [dB]	-20	-20	Minimum signal quality required to maintain LTE service
SINR [dB]	-10	-20	Required minimum signal to interference and noise ratio
HOSR [%]	95	95	HO threshold
Retainability [%]	98	98	Retainability threshold
AvgCellThroughput [Kbps]	150	150	Retainability threshold
Distance <sub>95</sub> [%]	95	95	Distance <sub>95</sub> threshold
Adjust pilot power of neighbor cells	disabled	enabled	Neighbor cell optimization flag
neighbor cell pilot power of neighbor cell: %	-	-9 dB	<i>neighborCellMaximumPilotPowerAdjustmentRange</i>
Pilot power step down for neighbor cell dB	-	0,6	Neighbor cell adjustment step
Pilot power step up for neighbor cell dB	-	0,6	Neighbor cell adjustment step

TABLE III. ADAPTIVE ROOT CAUSE ANALYSIS DIAGNOSIS RESULTS

CM	Run 1				Run 2				Run 3				
Cell Id	LTE-1	LTE-2	LTE-3	LTE-4	LTE-5	LTE-6	LTE-7	LTE-8	LTE-9	LTE-10	LTE-11	LTE-12	LTE-13
Cell power	32.0	32.0	33.6	33.6	33.0	31.5	33.0	33.0	-	32.5	32.0	-	-
PM													
wcel.cell-downlink-load	70	70	50	40	50	70	50	10	40	40	70	10	-
wcel.uplink-interference-level	2	2	2	2	2	2	2	2	2	2	2	2	-
wcel.total-number-of-ishos	0	0	0	0	0	0	0	0	0	0	0	0	-
wcel.isho-rscp-ecno-share	0	0	0	0	0	0	0	0	0	0	0	0	-
wcel.cell-edge-ecno	5	5	5	5	5	5	5	5	5	5	5	5	-
wcel.average-active-set-size	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.2	1.7	-
Expert Additional Input	Code												
Code	C3	-	-	-	-	-	-	-	-	-	-	-	-
Diagnosis Code	1	3	-	5	20	20	50	5	20	20	50	5	-
Diagnosis Abbreviation	CH	MN	?	PP	OS	SC	50	5	20	20	50	5	OK