



Q-Learning Algorithm for VoLTE Closed-Loop Power Control in Indoor Small Cells

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MOTIVATION

Downlink VoLTE Power Control (PC)

- Network impairments impact SNR and data rates
- LTE and 5G NR do not have downlink power control
- Link adaptation is instead used in the downlink
- Network intelligence enables cleaner communications
- Current practice:
 - Diversity and more robust modulation and coding
- Proposed:
 - Reinforcement learning is used to maximize SNR

Goal

- Enable downlink power control for indoor voice bearer
- Data is 60% likely to be on VoM-FD

Approach

- Q-learning improves the downlink SNR through:
 - Performing exploration and exploitation
 - Running until it finds a near-optimal policy

NETWORK MODEL

- An indoor OFDM-based cellular cluster in the FDD mode of operation
- Multi-user multiple access with one tier of neighboring cells
 - Square geometry and mean size distance of length L
- Network impairments regularly occurring at random
- PC keeps track of forward link SNR and potential radio impairments

Forward link budget for the i -th user

$$P_{\text{rx}}[i] = P_{\text{tx}}[i] + G_{\text{Tx}} - L_{\text{ra}} - L_{\text{fr}}[i] + G_{\text{rx}}$$

$$P_{\text{tx}}[i] = \min\left\{P_{\text{tx}}^{\text{max}}, P_{\text{tx}}[i] - (1 + \eta[i])\gamma[i]\right\}$$

Power control regulation (up to 3 times per TTI)



POWER CONTROL (PC) ALGORITHM ACTIONS AT TIME t

Action a	Definition
0	Nothing (this is a neutral action)
1	Down (PC = -1) executed (i.e., $\eta[i] = 0$)
2	Single (PC = +1) executed (i.e., $\eta[i] = 0$)
3	Single (PC = +1) executed
4	Three (PC = +1) executed

Algorithm:

VoLTE Power Control

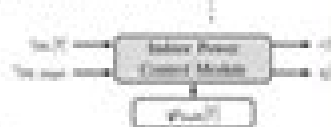
Given the set of fault-handling actions $a \in \mathcal{A}$ in a packetized voice frame τ of duration T ,

- Play an action a at random with π probability, or based on max future reward with probability $1 - \pi$
- Change the downlink transmit power per a
- Obtain the reward r_{t+1} and the next state i'
- Update π and $Q(\pi, a)$ accordingly
- Decay π and repeat for the next frame

PARAMETERS

Radio Network

Radio Network Parameters			
Parameter	Value	Parameter	Value
Carrier frequency	1.9 GHz	Antenna pattern	Omni
Bandwidth	10 MHz	Drop model	Drop
To BS range	10 m	To BS range	10 m
To BS range	10 m	To BS range	10 m



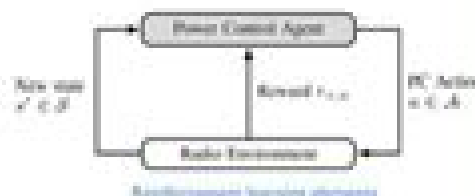
$$Q(\pi, a) \leftarrow (1 - \alpha)Q(\pi, a) + \alpha \left[r_{t+1} + \gamma \max_{a'} Q(\pi', a') \right]$$

The discounted future handling reward

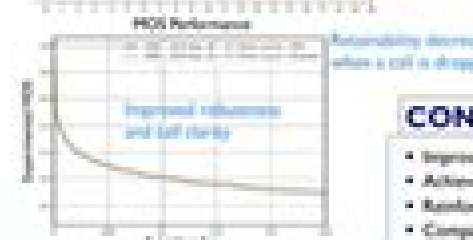
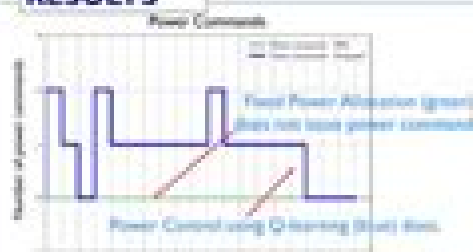
Q-Learning Parameters

Maximize (Learned) Parameters

Parameter	Value
Number of episodes E	100
One episode duration τ (sec)	30
Discount factor γ	0.95
High-value rate α	0.001
Minimum exploration rate ϵ_{min}	0.001
Exploration rate decay β	0.99
Learning rate η	0.001
Number of states	5
Number of actions	5



RESULTS



Parameter	Value
Fixed Power Allocation	0.001
Proposed	0.001

CONCLUSIONS

- Improved downlink SNR
- Achieved higher voice call reliability and clarity
- Reinforcement learning enables power control
- Compatible with LTE and 5G NR standards



Perspectives On Packetized Voice And Data Communications Frontiers In Communications

Arturo Cuomo



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