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Wireless channel scenario recognition based on neural networks

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Session 6: Machine learning for next generation wireless network

Paper S6.1: Wireless channel scenario recognition based on neural networks

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Paper S6.1: Wireless channel scenario recognition based on neural networks

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Outline

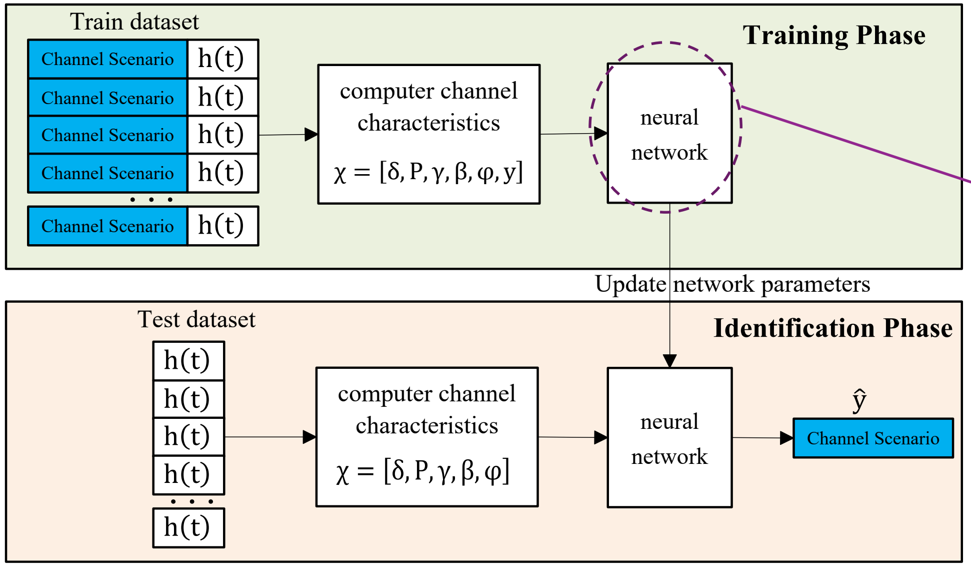
- Wireless channel scenario recognition algorithm model
- Wireless channel feature extraction
- Simulation results and conclusions

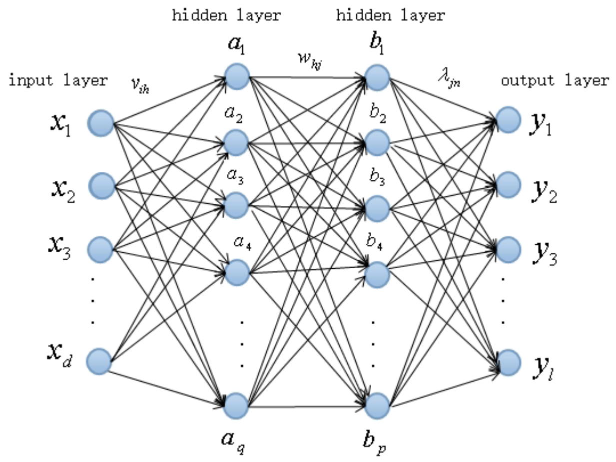
1. Wireless channel scenario recognition algorithm Model

If the different wireless channel scenarios could be identified, the adaptive receiving algorithm will be adopted to improve the performance of 4G or 5G communication systems. This paper proposes a wireless channel scenario recognition algorithm model based on neural networks.

✓ Two stages: offline training stage (supervised learning) and online recognition stage.

✓ Some key channel features (in time domain and frequency domain) from channel impulse response are extracted.



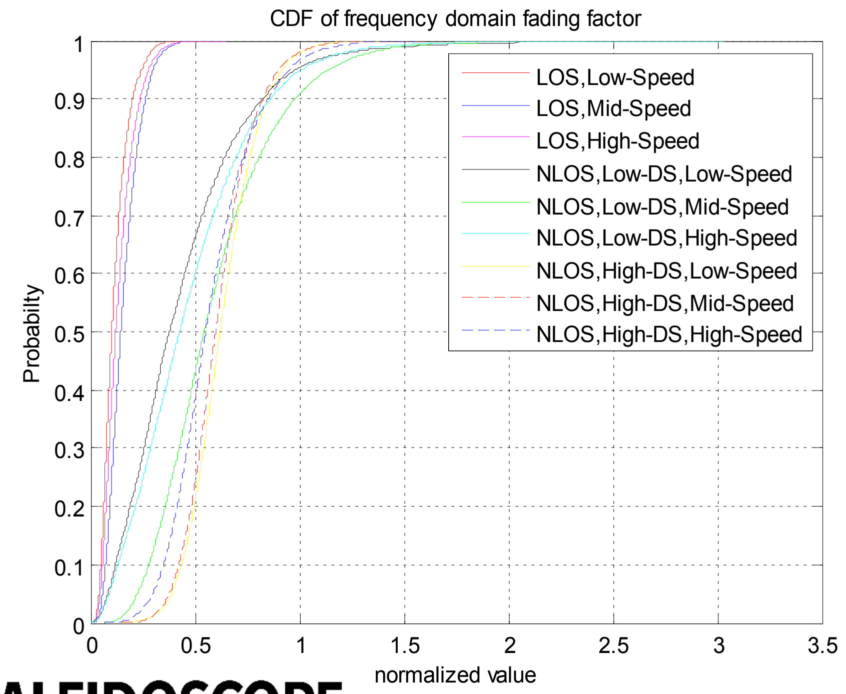


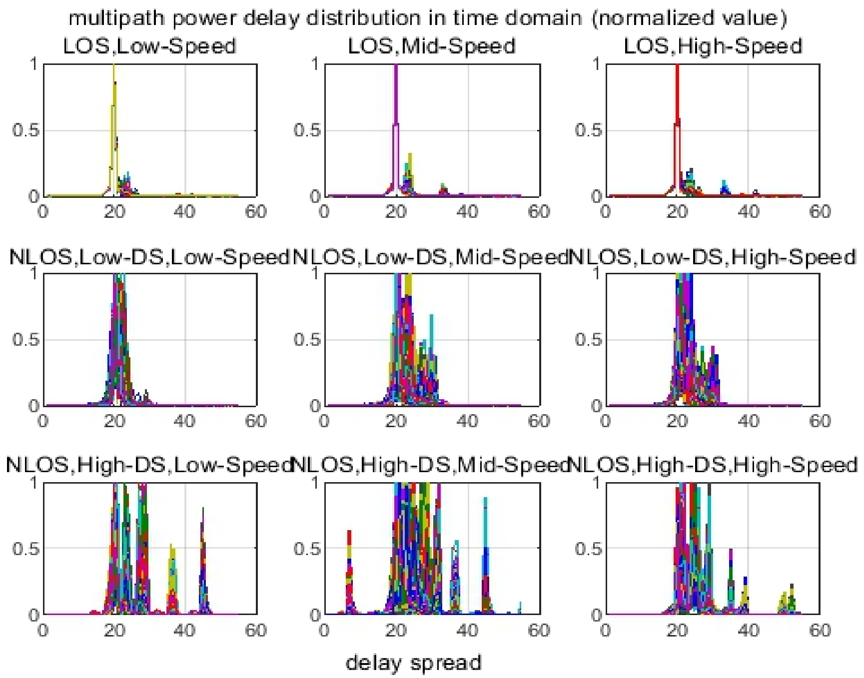
2. Wireless channel feature extraction

Some key channel features from channel impulse response are extracted as the channel characteristic set : $\chi=[\delta,P,\gamma,\beta,\varphi,y]$

- ✓ Frequency domain fading factor : $\delta(t)=\frac{1}{N_{RB}}\sum_{RB_i=0}^{N_{RB}-1}\left(P(RB_i,t)-\overline{P}(t)\right)^2/\overline{P}(t)$
- ✓ Multipath power delay distribution in the time domain: $P(\tau,t)=|h(\tau,t)|^2 \quad P(i,t)=\mathrm{F}[P(\tau,t)],\ i=0,1,\ldots,N_P-1$

$$\overline{P}(i,t)=\frac{P(i,t)}{\max(P(i,t))},i=0,1,\ldots,N_P-1$$



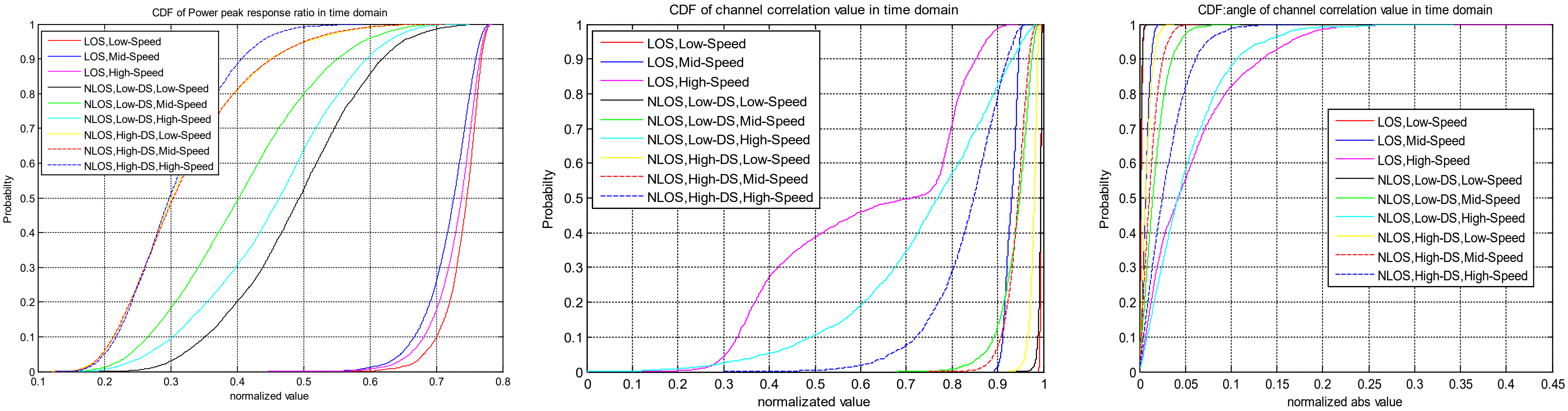


2. Wireless channel feature extraction

Some key channel features from channel impulse response are extracted :

- ✓ Channel power peak response ratio in the time domain γ : $\gamma(t)=\dfrac{\max(P(i,t))}{\sum_{i=0}^{N_P-1}P(i,t)}$
- ✓ Channel time correlation characteristics β_{norm},φ :

$$\beta(t)=\frac{1}{6N_{RB}-1}\sum_{k=0}^{6N_{RB}-1}\left(conj(h(k,s=0,t))\cdot h(k,s=1,t)\right) \qquad \beta_{norm}(t)=\frac{real[\beta(t)]^2}{P_1\cdot P_2} \qquad \varphi(t)=\frac{angle(\beta(t))}{\pi}$$



3. Simulation results and conclusions

The simulation models nine wireless channel scenarios proposed in Table 1, respectively using 4G and 5G channel models.

- ✓ LOS/NLOS: -> helpful to positioning and MU-MIMO pairing strategy
- ✓ Different UE Speeds: -> adaptive configuration of SRS period and the number of pilot symbols
  - Low speed: <= 30km/h
  - Medium Speed: 30-60km/h
  - High Speed: 60km/h.
- ✓ Different multipath delay spreads: -> adaptive channel estimation window
  - Low delay spread: Maximum multipath delay < 586ns
  - High delay spread: Maximum multipath delay < 2178ns.

Table 1 – Measurement wireless channel scenarios

1	Channel Scenario
1	LOS, Low Speed
2	LOS, Medium Speed
3	LOS, High Speed
4	NLOS, Low Delay Spread, Low Speed
5	NLOS, Low Delay Spread Medium Speed
6	NLOS, Low Delay Spread, High Speed
7	NLOS, High Delay Spread, Low Speed
8	NLOS, High Delay Spread Medium Speed
9	NLOS, High Delay Spread, High Speed

3. Simulation results and conclusions

1) Neural network classifier (proposed) VS traditional threshold classifier

✓ The traditional threshold classifier : the recognition accuracy of the first 4 channel scenarios is above 89%, but the recognition accuracy of other channel scenarios is very low. -> unsatisfactory, but easy to implement in hardware.

✓ The neural network classifier : the recognition accuracy rate for nine channel scenarios is above 90%. -> significantly improvement.

Confusion Matrix of Threshold Synthetic Decision

Actual class \ Predicted class	1	2	3	4	5	6	7	8	9
1	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.00%	99.90%	0.00%	0.00%	0.10%	0.00%	0.00%	0.00%	0.00%
3	0.00%	10.10%	89.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	5.90%	0.00%	0.00%	94.10%	0.00%	0.00%	0.00%	0.00%	0.00%
5	0.40%	0.00%	0.00%	35.90%	42.60%	3.40%	7.20%	9.70%	0.80%
6	3.50%	13.20%	9.00%	3.30%	17.90%	53.10%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	17.20%	0.40%	0.00%	78.40%	4.00%	0.00%
8	0.00%	0.00%	0.00%	7.00%	10.70%	0.20%	32.90%	47.90%	1.30%
9	0.00%	0.00%	0.00%	0.20%	11.90%	34.10%	0.20%	13.20%	40.40%

Confusion Matrix of Channel Feature 1 based on BP Neural Network

Actual class \ Predicted class	1	2	3	4	5	6	7	8	9
1	99.38%	0.25%	0.00%	0.25%	0.12%	0.00%	0.00%	0.00%	0.00%
2	0.00%	99.68%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	1.47%	98.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.41%	0.00%	0.00%	98.14%	0.62%	0.41%	0.41%	0.00%	0.00%
5	0.17%	0.00%	0.00%	2.58%	93.81%	3.26%	0.00%	0.17%	0.00%
6	0.00%	0.00%	0.13%	0.26%	3.44%	96.17%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	93.76%	4.56%	1.63%
8	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	8.05%	90.66%	1.11%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	2.00%	1.11%	96.83%

3. Simulation results and conclusion

2) The length of channel characteristic set has an impact on the classification performance.

✓ Table 2 gives two options for the length of channel characteristic set.

Channel feature 1: the longer window, and the higher multipath resolution.

Channel feature 2: the shorter window, and the lower multipath resolution

(Every 4 points are compressed into one point, so 36 point -> 9 points) .

Table 2–The length of multipath power delay distribution

Channel Feature	The length of multipath power delay distribution	The length of window L_1+L_2+1	The length of channel characteristics χ
1	L_1=18, L_2=36	55	226
2	L_1=9, L_2=26	36	46

✓ The higher the multipath resolution, the better the performance. But the channel feature 2 has fewer parameters of neural network (1/3 of channel feature 1), which can reduce the complexity of hardware implementation.

Confusion Matrix of Channel Feature 1 based on BP Neural Network

Actual class \ Predicted class	1	2	3	4	5	6	7	8	9
1	99.38%	0.25%	0.00%	0.25%	0.12%	0.00%	0.00%	0.00%	0.00%
2	0.00%	99.68%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	1.47%	98.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	0.41%	0.00%	0.00%	98.14%	0.62%	0.41%	0.41%	0.00%	0.00%
5	0.17%	0.00%	0.00%	2.58%	93.81%	3.26%	0.00%	0.17%	0.00%
6	0.00%	0.00%	0.13%	0.26%	3.44%	96.17%	0.00%	0.00%	0.00%
7	0.00%	0.00%	0.00%	0.05%	0.00%	0.00%	93.76%	4.56%	1.63%
8	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	8.05%	90.66%	1.11%
9	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	2.00%	1.11%	96.83%

Confusion Matrix of Channel Feature 2 based on BP Neural Network

Actual class \ Predicted class	1	2	3	4	5	6	7	8	9
1	99.38%	0.00%	0.00%	0.49%	0.12%	0.00%	0.00%	0.00%	0.00%
2	0.00%	99.68%	0.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3	0.00%	1.34%	98.53%	0.00%	0.00%	0.12%	0.00%	0.00%	0.00%
4	0.52%	0.00%	0.00%	96.39%	0.82%	0.41%	1.75%	0.00%	0.10%
5	0.17%	0.00%	0.00%	3.78%	86.60%	4.47%	2.23%	0.52%	2.23%
6	0.00%	0.00%	0.26%	0.26%	3.70%	93.37%	0.00%	0.00%	2.42%
7	0.00%	0.00%	0.00%	0.87%	0.49%	0.05%	93.27%	4.12%	1.19%
8	0.00%	0.00%	0.00%	0.00%	1.03%	0.09%	9.43%	87.32%	2.14%
9	0.00%	0.00%	0.00%	0.00%	0.72%	1.00%	1.39%	1.56%	95.32%

3. Simulation results and conclusions

3) The performance of neural network classifier with different SNR values.

- ✓ Table 3 gives the recognition accuracy of channel feature 1 under different SNRs.
- ✓ The lower the SNR value, the worse the recognition accuracy, especially the “NLOS, high delay spread” scenario.

Table 3 –Accuracy of channel feature 1 based on BP neural network under different SNRs

SNR/dB	20	15	10	5	0
Scenario 1:LOS, Low Speed	99.38%	99.35%	99.31%	98.86%	97.11%
Scenario 2:LOS, Medium Speed	99.68%	99.52%	99.47%	99.31%	93.80%
Scenario 3:LOS, High Speed	98.53%	98.42%	98.25%	97.67%	92.49%
Scenario 4:NLOS, Low Delay Spread, Low Speed	98.14%	98.10%	98.04%	97.85%	97.72%
Scenario 5:NLOS, Low Delay Spread, Medium Speed	93.81%	93.80%	93.16%	93.04%	92.84%
Scenario 6:NLOS, Low Delay Spread, High Speed	96.17%	96.04%	95.41%	93.90%	88.21%
Scenario 7:NLOS, High Delay Spread, Low Speed	93.76%	92.70%	89.11%	84.14%	79.34%
Scenario 8:NLOS, High Delay Spread, Medium Speed	90.66%	86.81%	82.88%	77.80%	71.68%
Scenario 9:NLOS, High Delay Spread, High Speed	96.83%	96.76%	95.45%	90.64%	81.93%

3. Simulation results and conclusions

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4) Conclusions

- ✓ The wireless channel scenario classifier based on neural networks has a greater performance improvement than the traditional threshold algorithm. Under high SNR, the minimum recognition accuracy can reach 90.66%. But as the SNR decreases, the recognition accuracy will also decrease.
- ✓ The composition structure of the wireless channel characteristic set will also affect the recognition accuracy, such as the window length and the resolution of the multipath delay spread distribution.
- ✓ The proposed wireless channel characteristics are simple to calculate, easy to implement, and have high engineering application value.
- ✓ However, there are still some limitations in our work. For example, the recognition accuracy under low SNR needs to be further improved; and a system simulation needs to be constructed to verify the improvement of system performance based on wireless channel scenario recognition.

Nevertheless, we wish that our works can provide new insights and motivation for the study of wireless channel scenario recognition in 4G/5G commercial systems.

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Thank you!