VITERBI DECODING EMPLOYING A HETEROGENEOUS COGNITIVE RADIO FOR PUBLIC MOBILE COMMUNICATION SYSTEMS

Advanced Wireless Communication research Center
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National Police Academy

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Outline

1. Summary and Problems of Public Mobile Communication Systems (PMCS)
2. Application of Heterogeneous Cognitive Radio
3. Viterbi Decoding for the cognitive radio

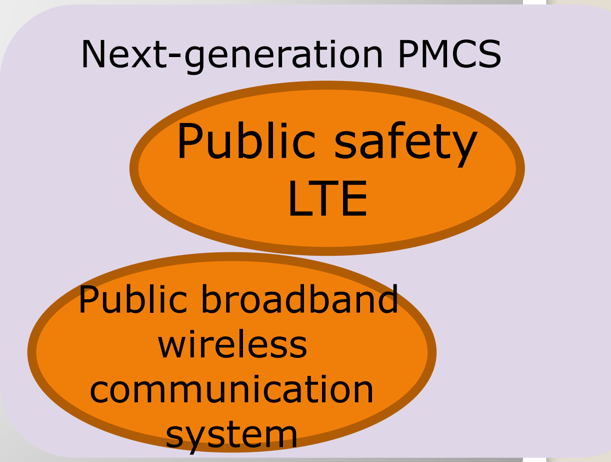
Outline

1. Summary and Problems of Public Mobile Communication Systems (PMCS)

   （1） Features of PMCS
   （2） Problems of the conventional PMCS
   （3） Next-generation PMCS

2. Application of Heterogeneous Cognitive Radio

3. Viterbi Decoding for the cognitive radio



1 Summary and Problems of Public Mobile Communication Systems (PMCS)

(1) Features of Public Mobile Communication systems(PMCS)

Europe · USA

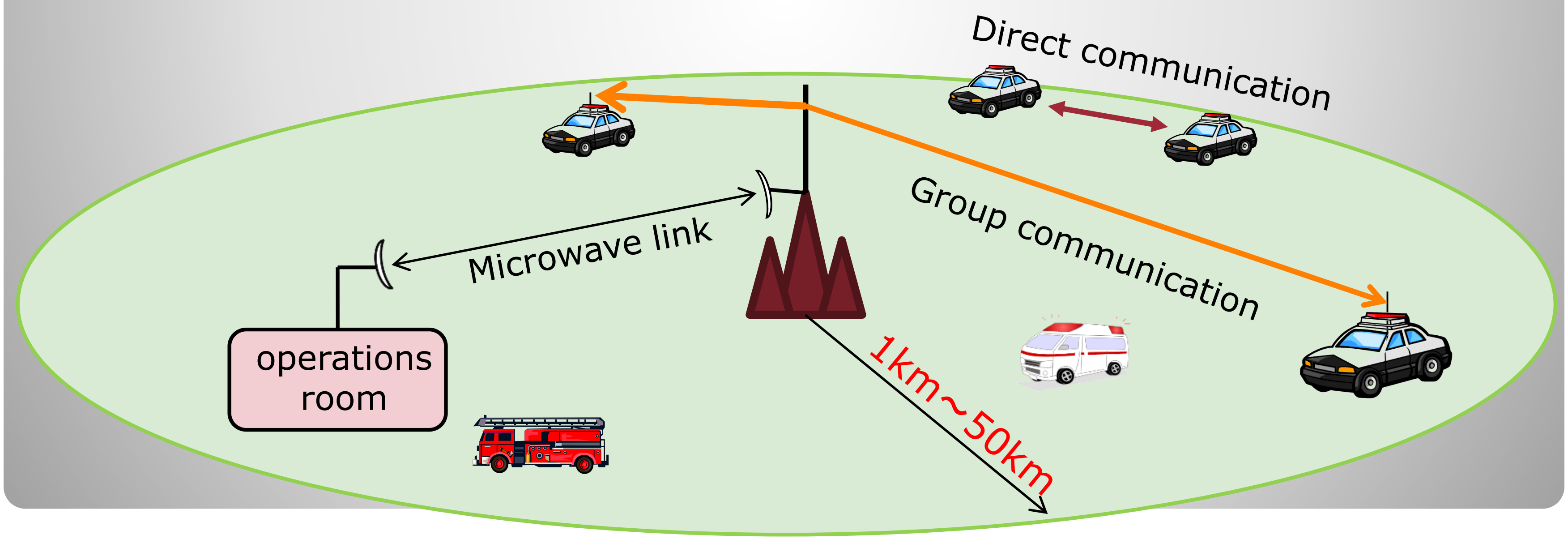
- TETRA（Terrestrial Trunked Radio)
- P25 (Project 25)

Japan

ARIB (Association of Radio Industries and Businesses)

- RCR STD-39
- RCR T79

· large zone scheme
· Narrow band
· group communication
· direct communication



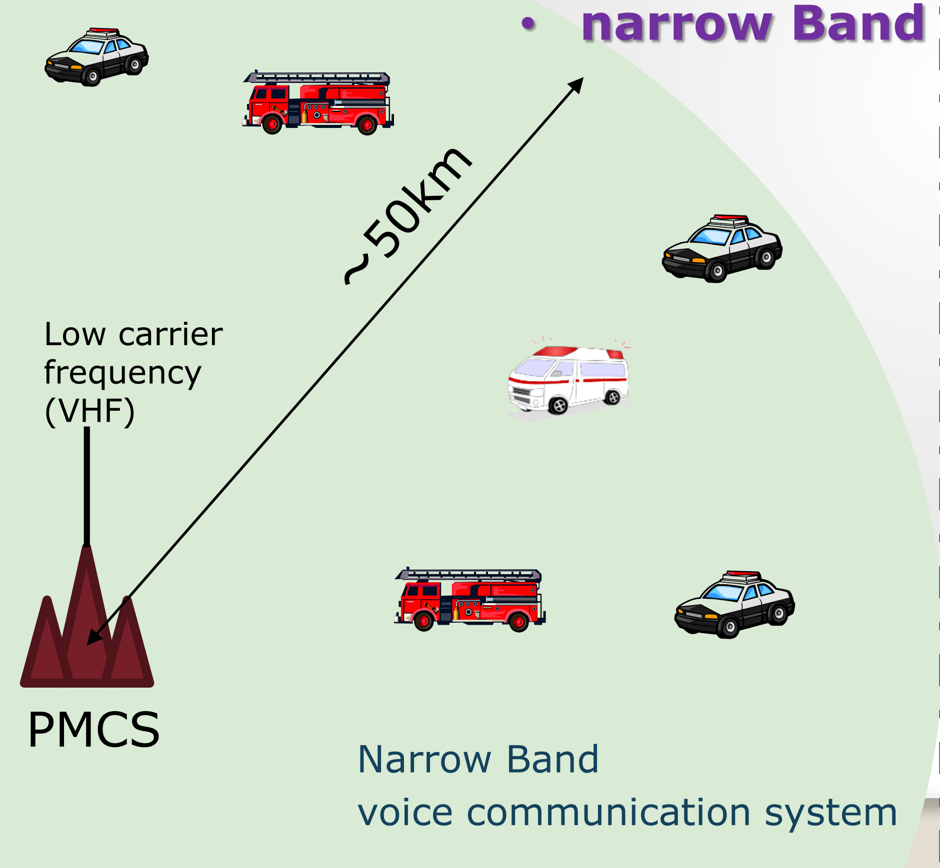
1 Summary and Problems of Public Mobile Communication Systems (PMCS)

(2) Problems of the conventional PMCS

- Realization of high-speed communication
- Improvement of coverage in urban area

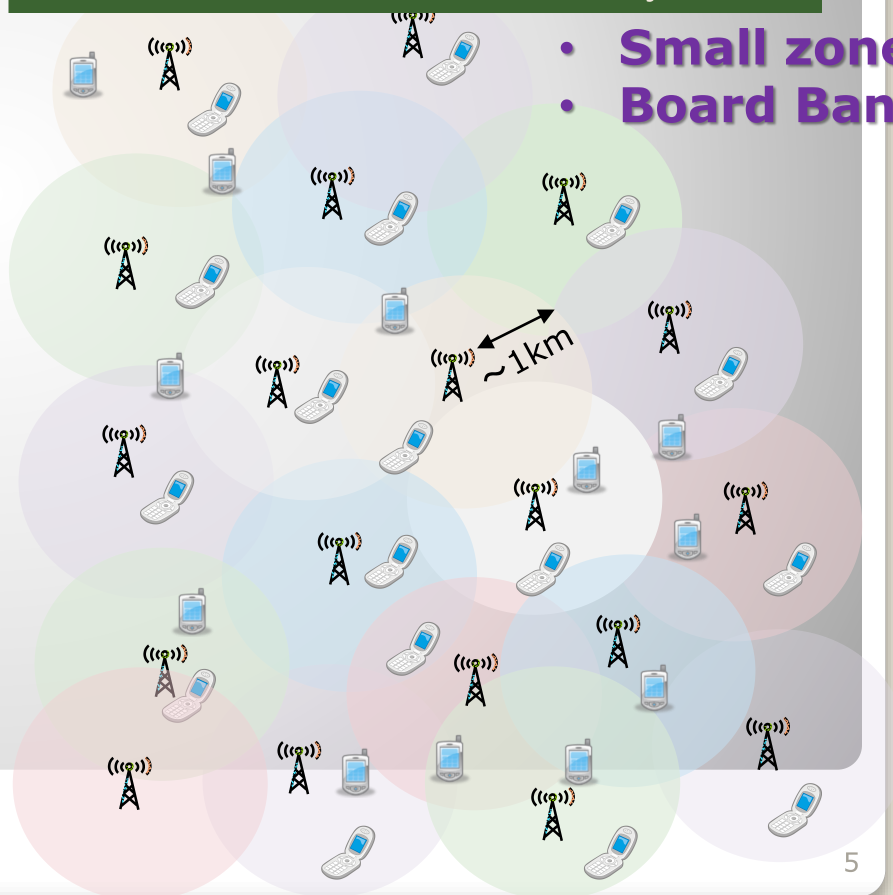
Public Mobile Communication Systems (PMCS)

- large zone
- narrow Band



Commercial mobile communication systems

- Small zone
- Board Band



1 Summary and Problems of Public Mobile Communication Systems (PMCS)

(3) Next-generation Public Mobile Communication Systems (PMCS)

Technical Features for LTE Public Safety

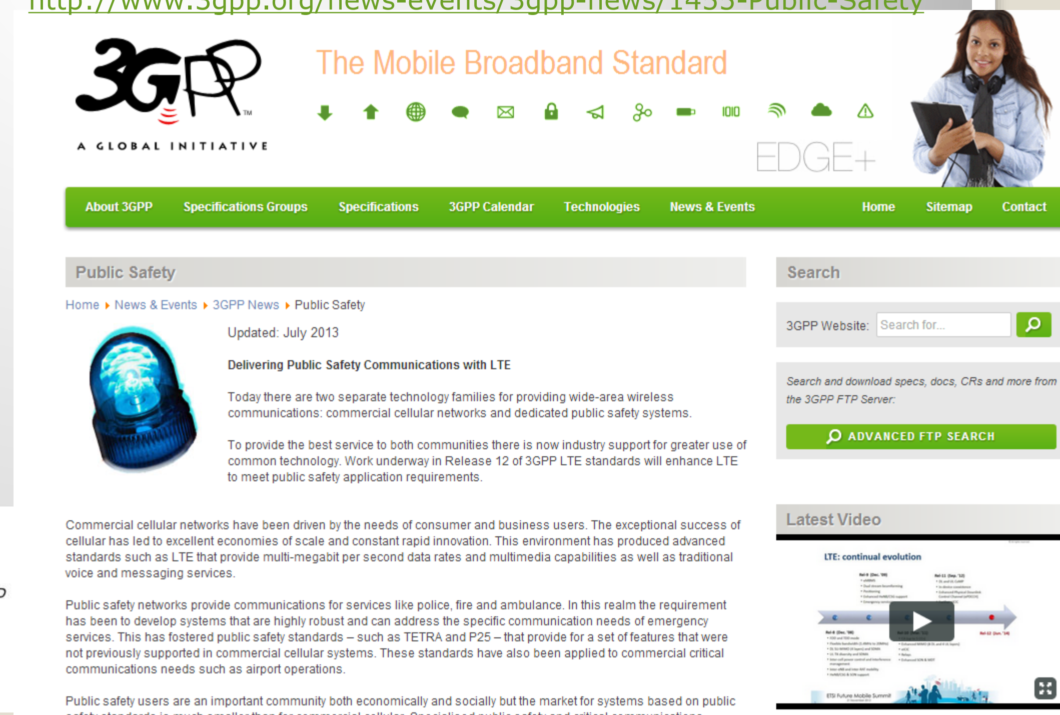
- Group Communication
- Direct Communication

Next-generation PMCS

Public safety LTE

Public broadband wireless communication system

(Reference)
http://www.3gpp.org/news-events/3gpp-news/1455-Public-Safety


The Mobile Broadband Standard

A GLOBAL INITIATIVE

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Public Safety

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Updated: July 2013

Delivering Public Safety Communications with LTE

Today there are two separate technology families for providing wide-area wireless communications: commercial cellular networks and dedicated public safety systems.

To provide the best service to both communities there is now industry support for greater use of common technology. Work underway in Release 12 of 3GPP LTE standards will enhance LTE to meet public safety application requirements.

Commercial cellular networks have been driven by the needs of consumer and business users. The exceptional success of cellular has led to excellent economies of scale and constant rapid innovation. This environment has produced advanced standards such as LTE that provide multi-megabit per second data rates and multimedia capabilities as well as traditional voice and messaging services.

Public safety networks provide communications for services like police, fire and ambulance. In this realm the requirement has been to develop systems that are highly robust and can address the specific communication needs of emergency services. This has fostered public safety standards – such as TETRA and P25 – that provide for a set of features that were not previously supported in commercial cellular systems. These standards have also been applied to commercial critical communications needs such as airport operations.

Public safety users are an important community both economically and socially but the market for systems based on public

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Latest Video

LTE: continual evolution

Developing Standards for LTE Public Safety Applications in 3GPP
→Release 12

1 Summary and Problems of Public Mobile Communication Systems (PMCS)

(3) Next-generation Public Mobile Communication Systems

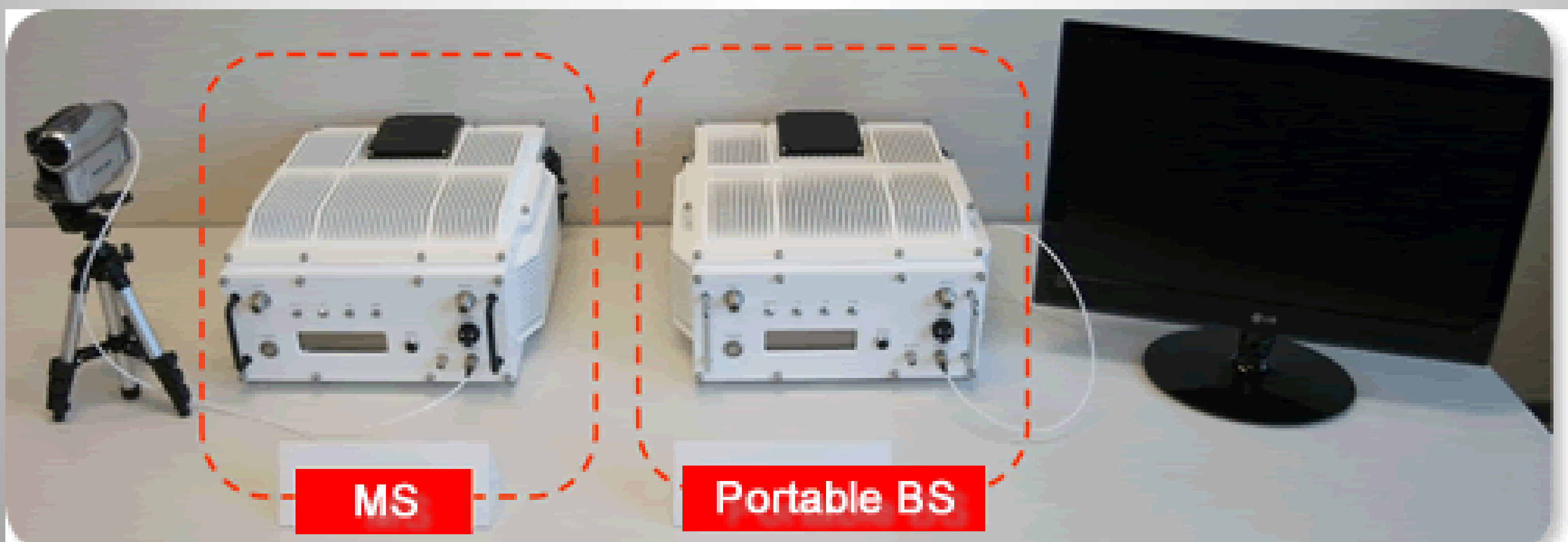
Next-generation PMCS

Public safety LTE

Public broadband wireless communication system

Japan

32.5 MHz (170–202.5 MHz) of new bandwidths can be allocated for public safety’s systems.



(Reference) National Institute of Information and Communication Technology (NICT)
http://www2.nict.go.jp/wireless/smartlab/project/pbb.html

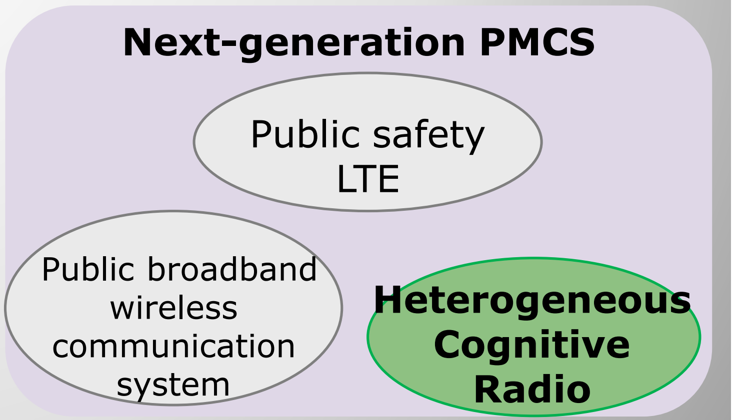
Outline

1. Public Mobile Communication Systems

2. Application of Heterogeneous Cognitive Radio

   (1) Advantages of the Heterogeneous Cognitive Radio
   (2) Constraint conditions
   (3) System structure

3. Viterbi Decoding

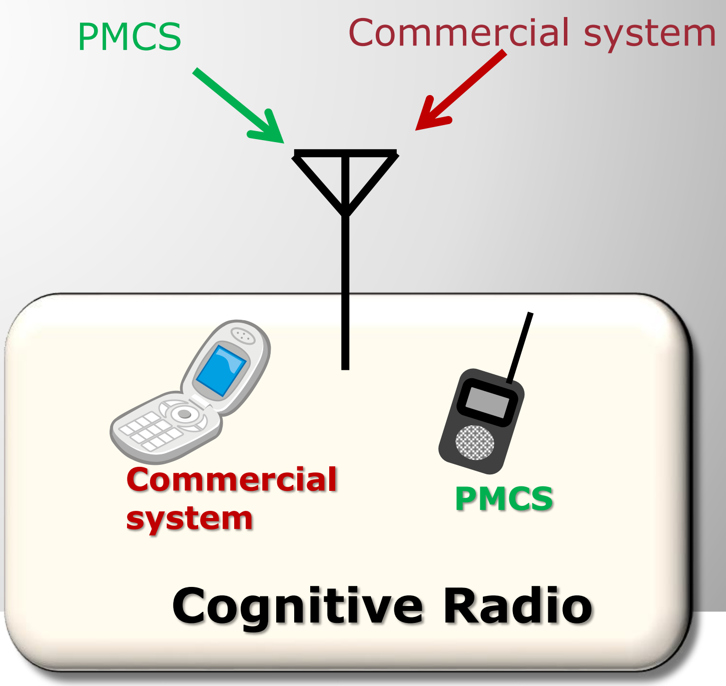


2 Application of Heterogeneous Cognitive Radio

(1) Advantages of the Heterogeneous Cognitive Radio

➢ Advantages of Implementation

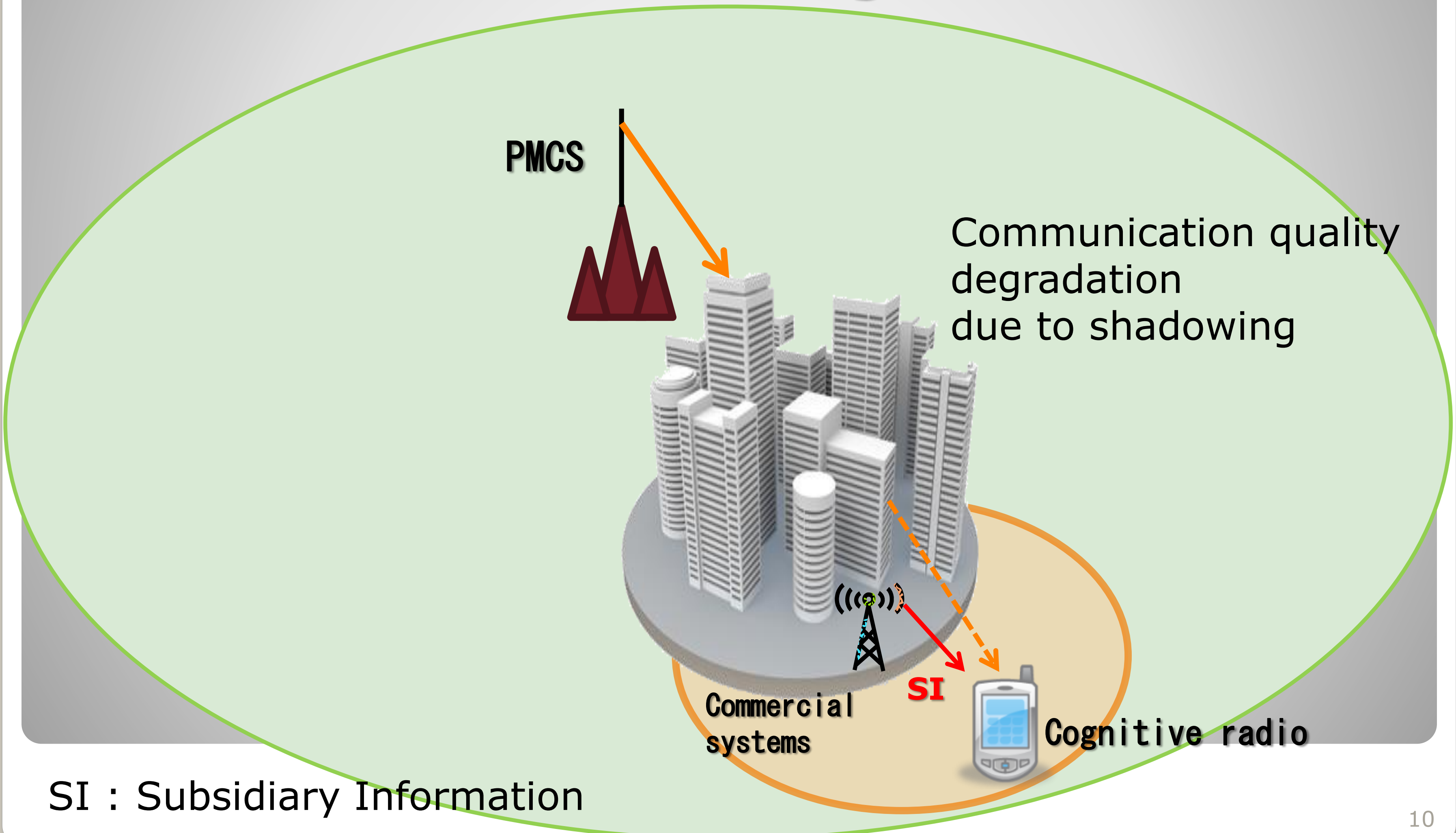
- Obtainment of new coverage
- High-speed Communication
- Inexpensive System



2 Application of Heterogeneous Cognitive Radio

(1) Advantages of the Heterogeneous Cognitive Radio

Obtainment of new coverage

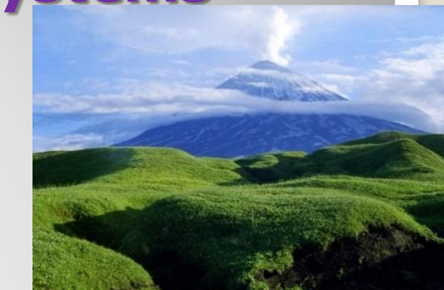


SI : Subsidiary Information

2 Application of Heterogeneous Cognitive Radio

(2) constraint conditions

1 Ability to Operate without Commercial Systems



The PMCS may be used in mountainous area or sea area.

2 Saving Resources of Commercial Systems

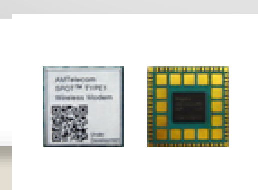
The cognitive radio must reduce the resource consumption of the commercial systems as possible.

3 Avoidance of Eavesdropping

Divulging significant information from the commercial systems should be avoided.

4 Using existing modules for Commercial systems

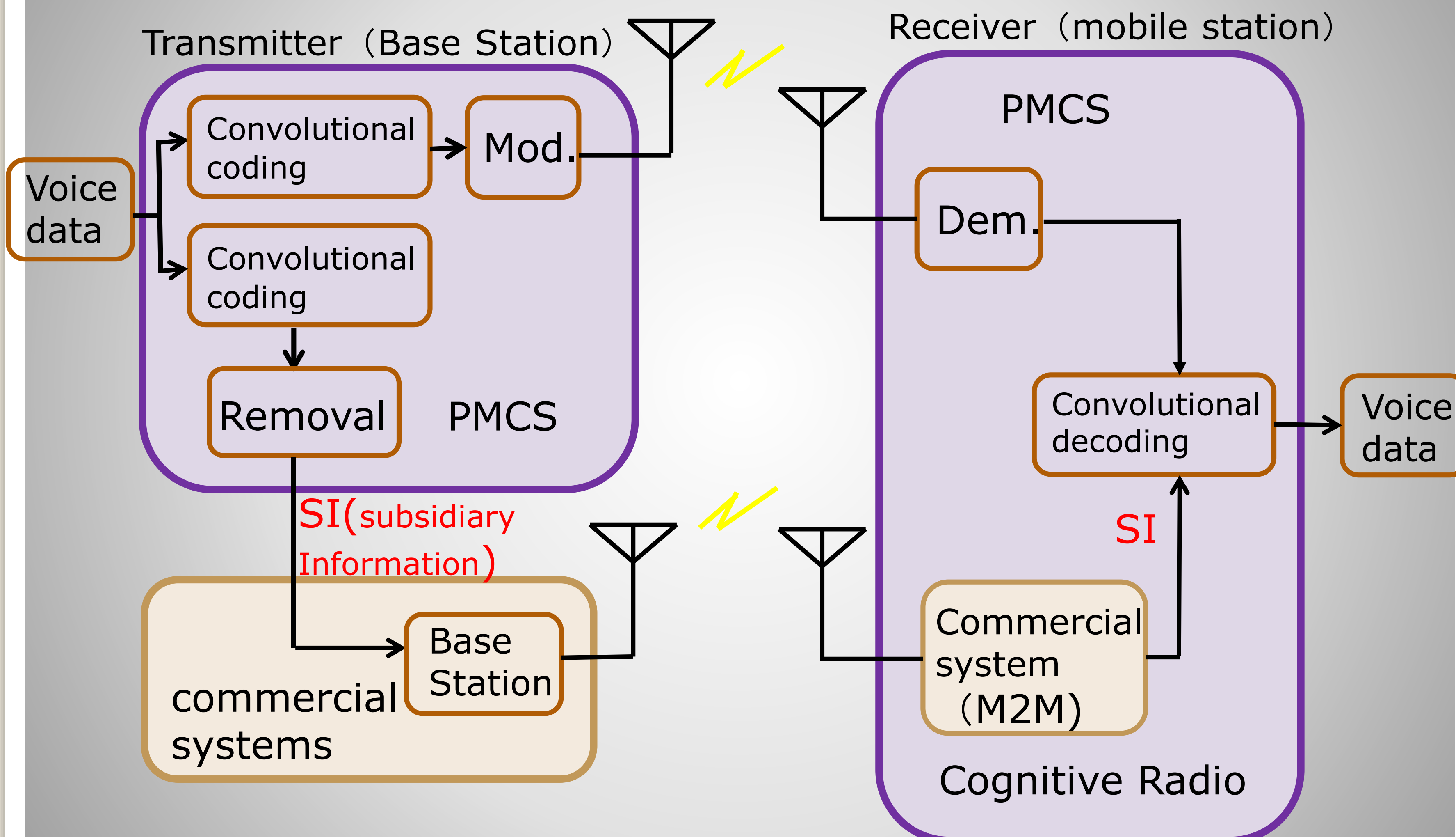
Application of M2M（Machine to Machine) modules
→The Cognitive Radio want to be realized inexpensively



Qualcomm：Machine-to-Machine Cellular Modules
http://www.m2msearch.com/cellular-modules

2 Application of Heterogeneous Cognitive Radio

（3） system structure



Outline

1. Public Mobile Communication Systems

2. Application of Heterogeneous Cognitive Radio

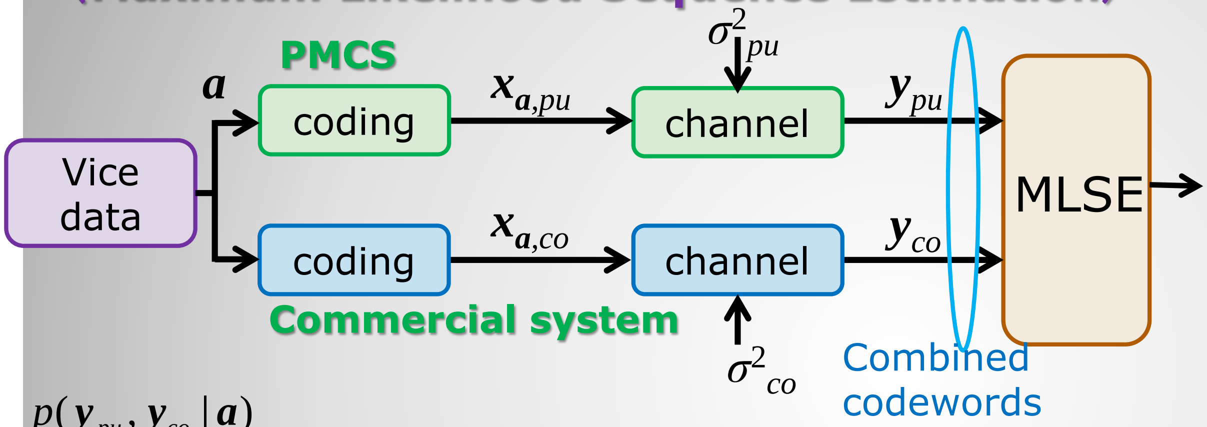
3. Viterbi Decoding for the cognitive radio

（1） Modified Viterbi algorithm
（2） Optimal generator polynomial
（3） Evaluation of the proposed system

3 Viterbi Decoding for the cognitive radio

(1) Modified Viterbi algorism

MLSE
(Maximum Likelihood Sequence Estimation)



Parameter of combined codewords

Information bits	$\boldsymbol{a}$
Code length	L
Receive signals of the PMCS	$\boldsymbol{y}_{pu}$
Code words of the PMCS	$\boldsymbol{x}_{\boldsymbol{a},pu}$
Noise power of the PMCS*	$\sigma^2{}_{pu}$
Receive signals of commercial system	$\boldsymbol{y}_{pu}$
Code words of commercial System	$\boldsymbol{x}_{\boldsymbol{a},co}$
Noise power of commercial system*	$\sigma^2{}_{co}$

*normalized by power of received signals

$$p(\boldsymbol{y}_{pu},\boldsymbol{y}_{co}\,|\,\boldsymbol{a})$$
$$=\left(\frac{1}{2\pi\sigma_{pu}^2\sigma_{co}^2}\right)^L\prod_{l=1}^{L}\exp\left(-\frac{|\boldsymbol{y}_{pu}(l)-\boldsymbol{x}_{\boldsymbol{a},pu}(l)|^2}{2\sigma_{pu}^2}\right)\exp\left(-\frac{|\boldsymbol{y}_{co}(l)-\boldsymbol{x}_{\boldsymbol{a},co}(l)|^2}{2\sigma_{co}^2}\right)$$

Taking logarithm

$$LLF(\boldsymbol{y}_{pu},\boldsymbol{y}_{co}\,|\,\boldsymbol{a})=\sum_{l=1}^{L}\left(\frac{\boldsymbol{y}^T{}_{pu}(l)\cdot\boldsymbol{x}_{\boldsymbol{a},pu}(l)}{\sigma_{pu}^2}+\frac{\boldsymbol{y}^T{}_{co}(l)\cdot\boldsymbol{x}_{\boldsymbol{a},co}(l)}{\sigma_{co}^2}\right)+U'$$

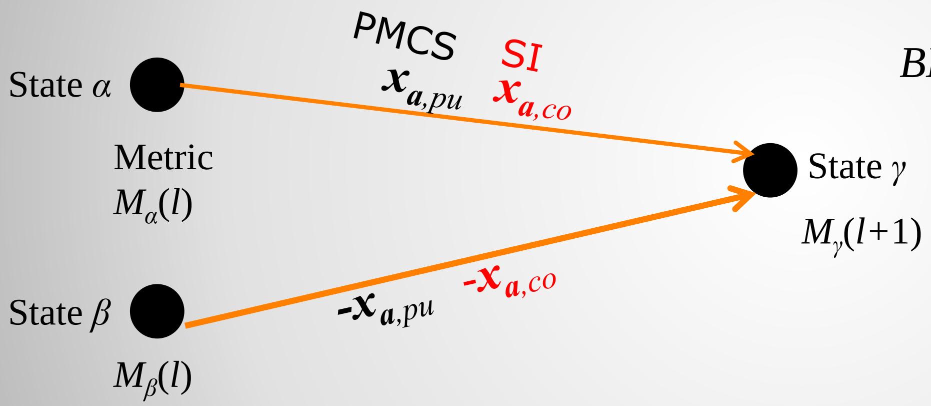
U': constant value

3 Viterbi Decoding for the cognitive radio

(1) Modified Viterbi algorithm

Viterbi Algorithm

$$LLF(\boldsymbol{y}_{pu}, \boldsymbol{y}_{co} \mid \boldsymbol{a}) = \sum_{l=1}^{L} \left(\frac{\boldsymbol{y}^T{}_{pu}(l) \cdot \boldsymbol{x}_{\boldsymbol{a},pu}(l)}{\sigma_{pu}^2} + \frac{\boldsymbol{y}^T{}_{co}(l) \cdot \boldsymbol{x}_{\boldsymbol{a},co}(l)}{\sigma_{co}^2} \right) + U'$$



$$BR(l) = \frac{\boldsymbol{y}^T{}_{pu}(l) \cdot \boldsymbol{x}_{\boldsymbol{a},pu}(l)}{\sigma_{pu}^2} + \frac{\boldsymbol{y}^T{}_{co}(l) \cdot \boldsymbol{x}_{\boldsymbol{a},co}(l)}{\sigma_{co}^2}$$

Noise power

$$M_\gamma(n+1) = \max\{M_\alpha(n) + BR_{\alpha\to\gamma}(l) \quad , \; M_\beta(n) + BR_{\beta\to\gamma}\}$$

The difference from the normal Viterbi algorithm
$\rightarrow$ $BR(l)$ is divided by σ^2_{pu} and σ^2_{co}.

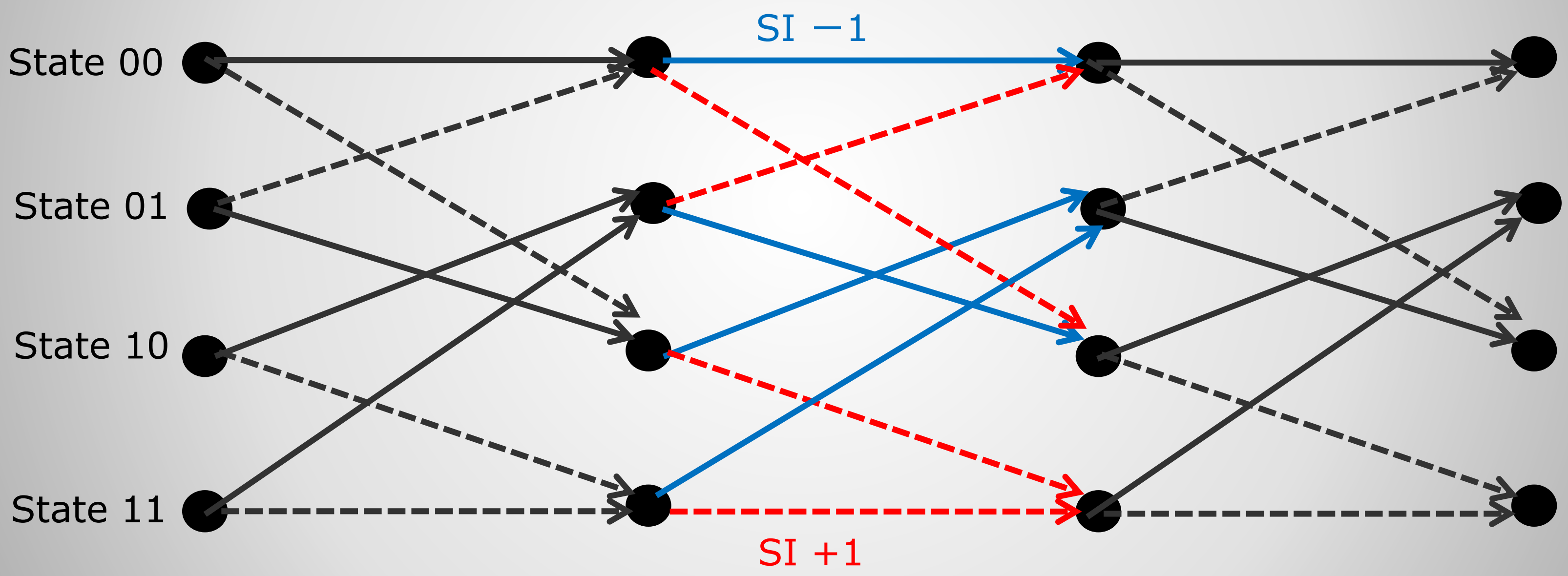
3 Viterbi Decoding for the cognitive radio

(1) Modified Viterbi algorism

In the case of correct (hard decision) values SI
→ simplify of the Viterbi Algorithm

Example)
Constraint length K=3
Coding rate of SI R_{co}=1

Trellis diagram

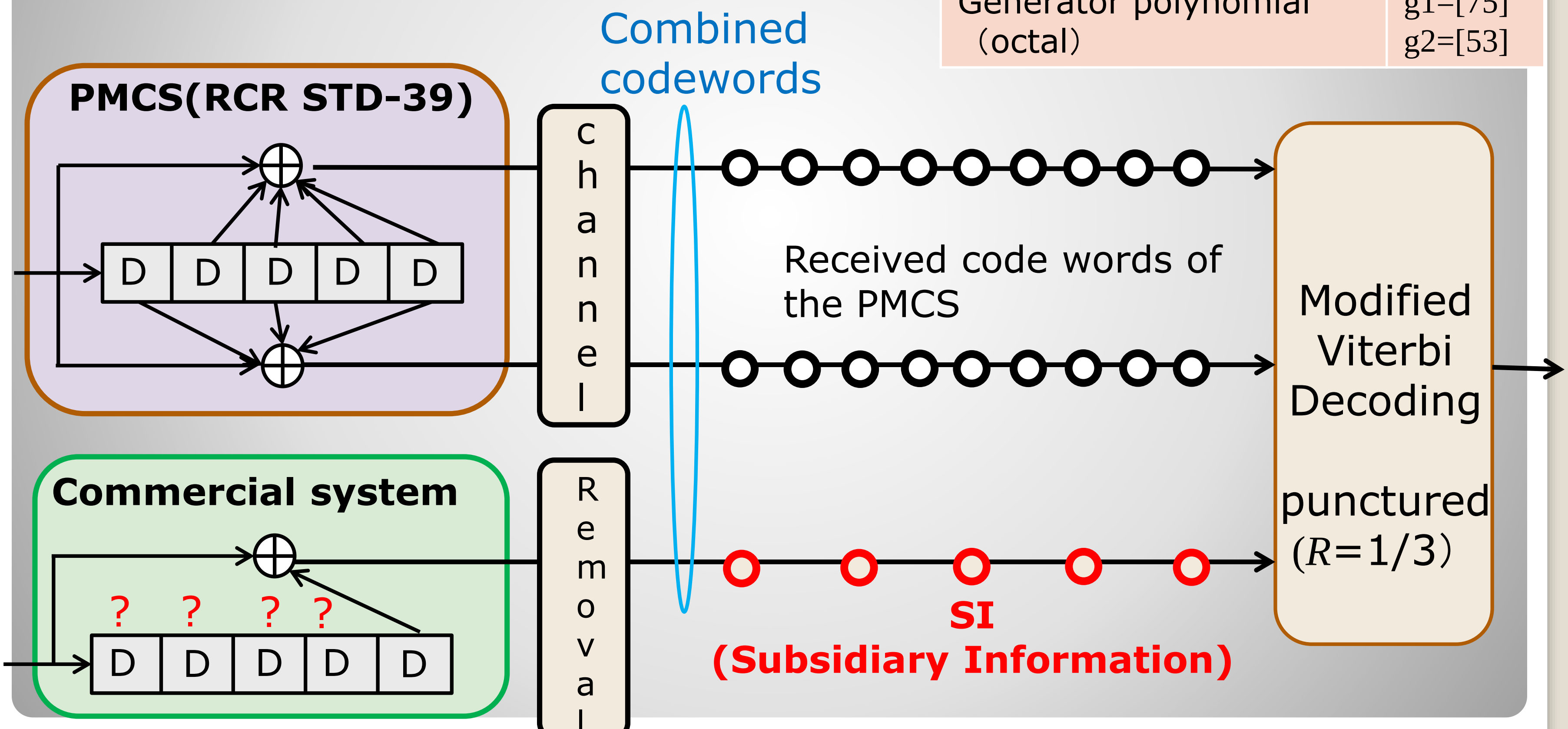


Paths are restricted if SI is correct values.

3 Viterbi Decoding for the cognitive radio

(2) Optimal generator polynomial

Convolutional code RCR STD-39	
Constrain length K	6
Coding rate R	½
Generator polynomial (octal)	g1=[75] g2=[53]



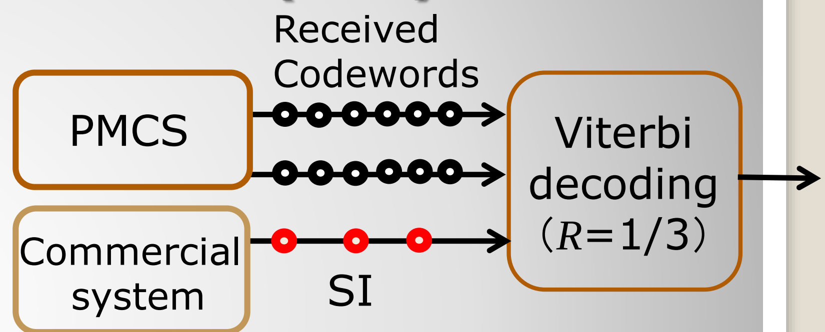
to improve BER performance effectively, we should search the best generator polynomial of the SI while removal rate is changed.

(2) Optimal generator polynomial

Distance Spectrum

In the case of correct hard decision values (CHD)

Distance (Free distance)	d (d_{free})
Number of wrong paths of distance d	$L(d)$
Number of errors on information bits of distance d	$N(d)$



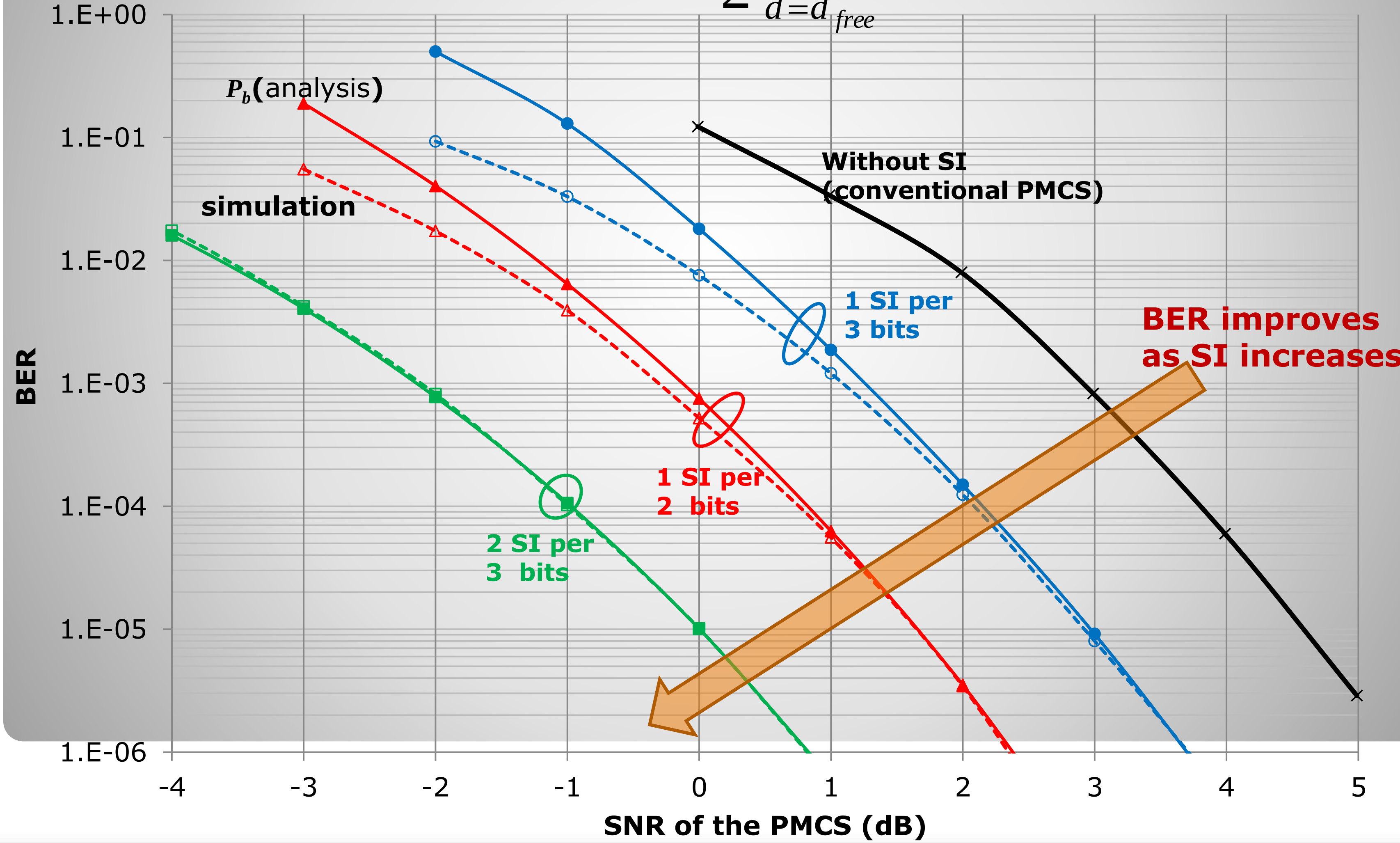
Rate of SI	Generator polynomial	d	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
2 SI per 3bits	53 (g2)	$L(d)$												1	1	0	0	0	0	0	1	2	1	2
		$N(d)$												7	8	0	0	0	0	0	12	22	10	22
	41 (optimal)	$L(d)$												1	0	0	0	0	1	1	2	1	1	0
		$N(d)$												3	0	0	0	0	6	9	18	9	6	0
1 SI Per 2 bits	53 (g2)	$L(d)$							2	0	1	0	1	0	9	0	16	0	34	0	62	0		
		$N(d)$							8	0	6	0	6	0	74	0	138	0	354	0	732	0		
	57 (optimal)	$L(d)$								1	2	0	0	4	5	5	8	7	9	23	33	35		
		$N(d)$								5	12	0	0	30	38	49	80	65	104	263	382	427		
Without SI R=1/2		$L(d)$	1	8	7	12	42	95	281															
		$N(d)$	2	36	32	62	332	701	2342															

3 Viterbi Decoding for the cognitive radio

(3) Evaluation of the proposed system

In the case of CHD

$$P_b < \frac{1}{2} \sum_{d=d_{free}}^{\infty} N'(d)\mathrm{erfc}\left(\sqrt{d \cdot SNR}\right)$$



Conclusion

- **General description of the PMCS**
- **Proposal of the cognitive radio for the PMCS**
- **Viterbi decoding for the cognitive radio**
  - **Modified Viterbi algorithm**
  - **Optimal generator polynomial for SI**
  - **BER performance**

Thank you very much.

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