

,

()

()

()

D2D

()

:

II

,

-20-1

(,)

123 «

'

»

()

-

(- -)

()

:

(, ,)

()

(,)

,

()

123 « ' »

()

-

()

:

“ ” 20 .

(, ,)

1. D2D

“ 05 ” 2021 . 1657

2. 13 2021 .

3. 1) ; 2) ; 3) CPU type: Mobile

Intel Core i5-430M, 2533 MHz (19 x 133); 4) – Windows 10;

5) : Multiprocessor Free (64-bit); 6) :

4. ,

1) ;

2) ;

3) ;

4) ;

5) .

5. _____ , _____ , _____ , _____ , _____
 () _____
 - -16

6. _____ , _____ .1) (_____)

	(_____ , _____ , _____ , _____)		

1		09.11.21 - 12.11.21	
2		13.11.21 - 18.04.21	
3		19.11.21 - 22.11.21	
4		23.11.21 - 29.11.21	
5		30.11.21 - 03.12.21	
6		08. 12.21 - 09.12.21	
7		10.12.21 - 11.12.21	

08 2021 .

_____ () _____
 | _____ () _____ (, ,)

: 60 ., 19 ., 1 ., 14

.

, , WI-FI.

- .

-

D2D

, .

,

D2D

, devices

, ,

, D2D,

devices,

, D2D.

ABSTRACT

Master's thesis: 60 pages, 19 figures, 1 appendices, 14 sources.

WIRELESS SENSOR NETWORK, PROTOCOL, WI-FI.

The purpose of the qualification work is to study the model of the random graph Erdesh - Rainy.

In the course of the qualification work, the model of the random Erdesch-Rainy graph is investigated to increase the efficiency of device clustering when using D2D interactions in mobile communication networks. This model, built using D2D technologies and allows to estimate the probability of connectivity of devices in mobile communication networks built using D2D type connections, in contrast to known models and is based on the model of random graphs and takes into account the properties of subscriber devices. support D2D connections.

, , ,

—
C —
—
—
—

,

,

D2D —
device»)

(., «device-

(«device-device» (D2D))

.

,

()

,

D2D

,

.

,

.

1

5G
()
2020. IMT-
IMT-2020 5G

2G 3G 4G
. 2G

, SMS-
3G
. 4G

Internet - -
- , .
,

, , ,
(1.1).
, « » (,
,) -

:
- ,

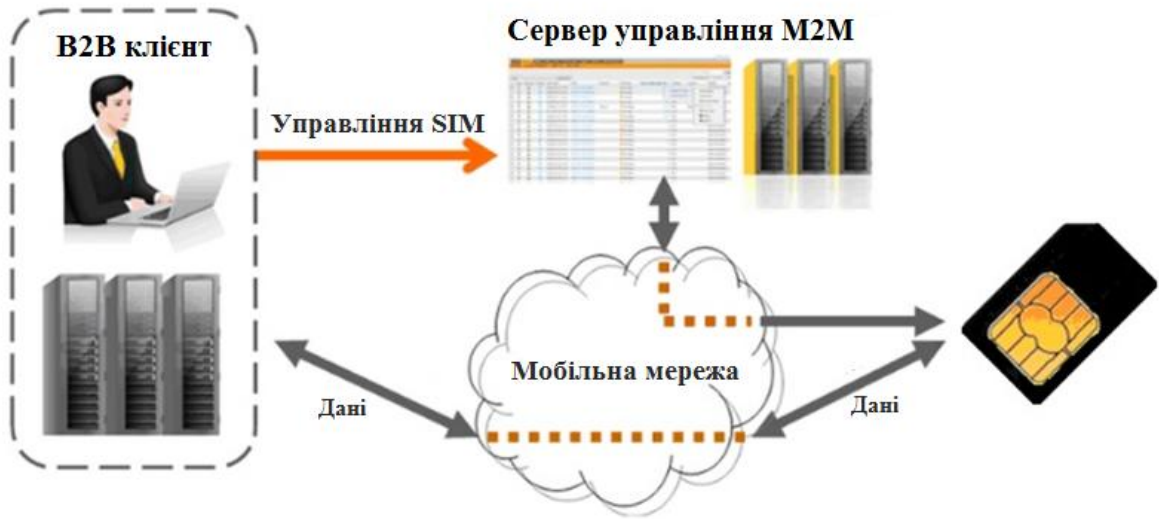
,

« - » (. «machine-machine») (M2M) (1.2) «
 » (. «internet of things» (IoT),
 , , ;



1.1 –

- , . , .
 , , , (4K), internet,
 , , , ,
 , 5G ,
 , , , ,
 , (IoT),
 , Internet.



1.2 – M2M

1.1 5G

4G

5G.

(5G)

IMT-2020

():

:

- 20 / .;

- 10 / .

1.2 5G

4G,

(5G) :
 - « » (IoT). IoT ,
 , Internet
 (1.3).



1.3 – IoT

IoT,

Internet.

IoT

IoT

(WSN)

(RFID).

IoT

D2D :

- (),

D2D.

- ;

- (D2D)

5G.

- PAN

;

-

;

- D2D

« » ;

- IoT, (V2V) (1.5) Internet

(IoV);

-

,



1.5 –

V2V

1.3

D2D

D2D

5G

,

:

-

A -

R (

)-

().

;

-

A -

B -

.

,

,

(

1.6).

,

D2D

A B.

A B,

,

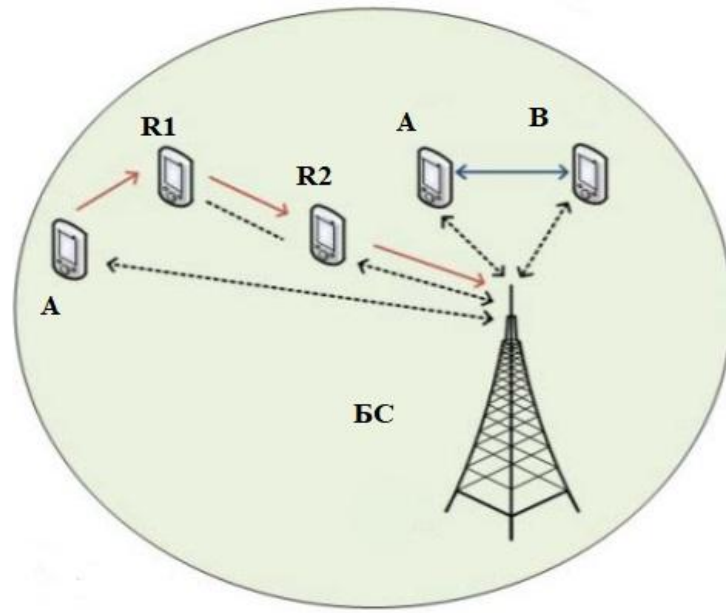
,

.

D2D

,

.



1.6 –

5G

1.4

D2D

5G

,

,

.

.

,

,

,

,

,

.

,

,

,

,

.

,

D2D-
(1.8).



1.8 –

D2D

D2D-

D2D-
 ,
 ,
 ,
 ,
 D2D-'
 (,).
 , D2D ,
 .

1.4.1 ' D2D

- ,
 , , .
 ,
 .
 D2D.
 , ,
 .
 Auranet
 (). , D2D-'
 « » .
 D2D-'
 ,
 .
 , CSI

D2D- ' :

-

,

;

-

;

-

,

.

,

— «

».

SINR,

,

,

,

.

,

D2D- ' .

LTE

:

-

;

-

MIMO,

D2D;

-

D2D;

-

D2D- ,

,

.

,

D2D

.

1.4.2 ' D2D

,

,

,

ISM.

.
 ,
 .
 (WLANs/WPANs) Wi-Fi Bluetooth
 . Wi-Fi- IEEE
 802.11, ,
 , ,
 .
 ,
 WLAN
 , ,
 ,
 .
 Wi-Fi.
 . Wi-Fi- ,
 ,
 .
 ,
 ,
 . Wi-Fi-Direct
 (WFD). ,
 Wi-
 Fi.
 WFD « » ,
 - , « » .
 « »
 « » , ,

WLAN

WFD-

ISM

WLAN,

(WFD/LTE),

MIMO,

D2D

WFD

D2D

D2D

D2D-

1.4.3

D2D

D2D-

:

-

;

-

,

.

,

.

,

,

/

,

,

.

,

D2D -

,

,

.

,

,

,

.

.

,

,

,

.

,

,

.

,

,

,

D2D -

,

,

.

-

D2D

- ,

.

, D2D-

, D2D- '

,

.

,

,

.

-

P2P,

3GPP

D2D -

,

.

P2P

,

.

-

,

Internet,

.

,

,

.

,

,

,

.

,

,

,

YouTube,

.

,

P2P-

D2D- '

. YouTube

,

,

Internet,

,

,

,

D2D

,

.

,

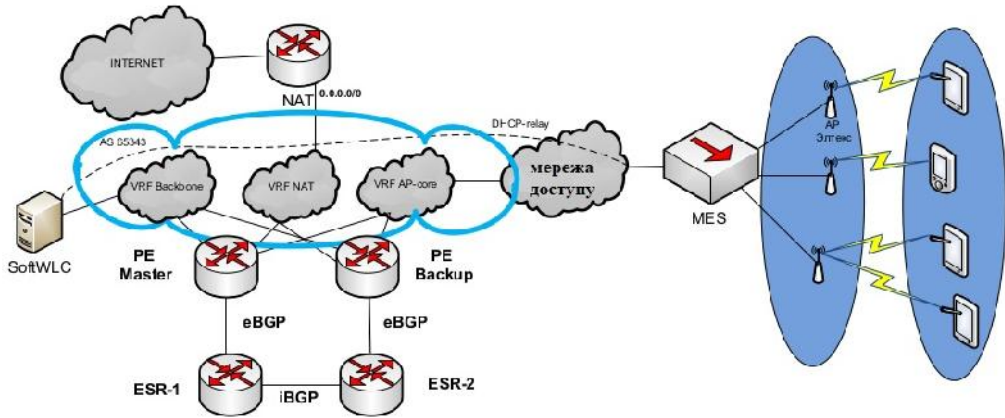
,

.

D2D- '

,

D2D- ,
 1.9 D2D-
 D2D- ,
 D2D -
 3GPP :
 D2D-
 ;
 3GPP- ,
 D2D-
 ;
 - D2D,



1.9 –

D2D

2

,

2.1

,

,

.

,

,

.

,

,

.

,

,

,

.

,

,

,

.

,

,

.

,

,

,

,

,

.

,

,

,

(

).

,

,

-

.

,

.

,

,

-

.

,

,

,

-

,

.

,

,

.

,

«

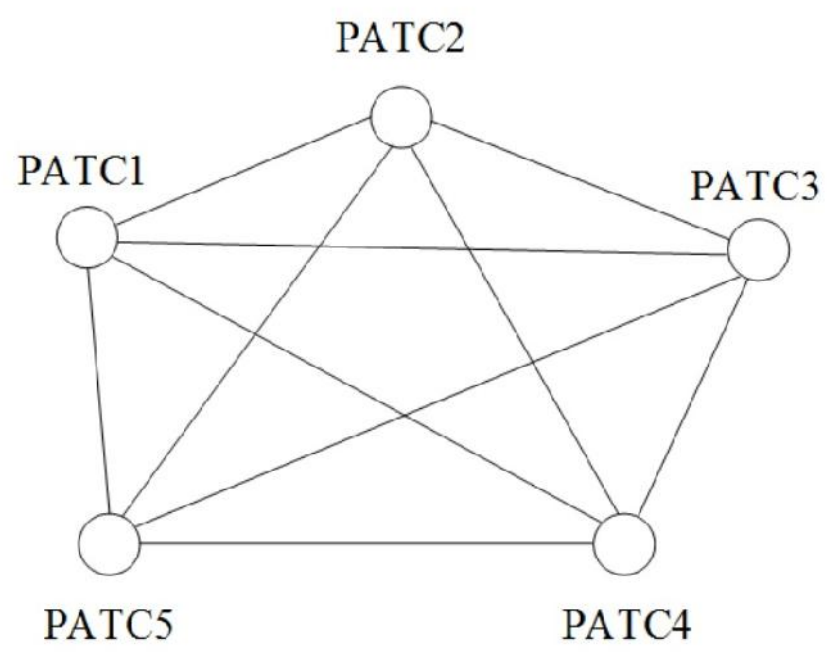
».

,

" "

()

(2.3).



2.3 –

,
 .
 ,
 :
 - ' (') ;
 - ;
 - , ,
 ,
 - , , .
 ,
 , , (,
 ') .
 ,
 - ,
 .
 « ' » . ,
 ,
 (' ,) . ,
 ,
 ()
 .
 , , ,
 .
 , ()
 , , .
 , , , ,
 , , , , .
 , , .

$$p_c = \lim_{n \rightarrow \infty} \frac{n_0}{n^2}, \quad (2.1)$$

$n -$

;

$n_0 -$

2.2 ’

HetNet

(2.4).



2.4 –

HetNet

WLAN.

MIMO (Multiple Input Multiple Output),

Wi-Fi,

(2.5). IoT D2D-



2.5 – D2D 5G

2.3 , D2D

device (, 5G device

device (,).

$$G = \{V_n, E\}, \tag{2.1}$$

$V_n = \{1, 2, \dots\}$, —
 , device- ,
 E;
 E — ,
 $P_{i,j}$.
 $P_{i,j}$,
 $i \quad j$ — ,
 $P_{i,j}$,
 — ,
 , :

$$G(n, p_{i,j}) = (\Omega_n, F_n, P_{n, p_{i,j}}), \tag{2.2}$$

:

$$\Omega_n = \{G = \{V_n, E\}\}, \tag{2.3}$$

:

$$\begin{array}{l}
 G(H_n, p_{i,j}) \\
 \hline
 H_n = (V_n, E_n)
 \end{array}
 \tag{2.4}$$

:

$$p_{i,j} = \begin{cases} p, & (i,j) \in E_n \\ 0, & (i,j) \notin E_n \end{cases}, \tag{2.5}$$

$$P_{n,p_{i,j}}(G) = p^{|E|}(1-p)^{|E_n|-|E|}, \tag{2.6}$$

$|E| -$.
 $p -$.
 , .
 , :

$$p = \frac{\ln(n)}{n}, \tag{2.7}$$

$-$, :
 $> 1,$ $P((G, n, p)) \rightarrow 1,$ (2.8)

, . :
 $< 1,$ $P((G, n, p)) \rightarrow 0,$ (2.9)

, . :
 $= 1,$ $P((G, n, p)) \rightarrow e^{-1},$ (2.10)

, (2.7) ,
 , , :

$$> 1, \quad (2.11)$$

n :

$$P(G) \geq c \cdot p_0, \quad (2.12)$$

:

$$G(n, p_{i,j}), \quad (2.13)$$

, . :

$$< 1, \quad (2.14)$$

n :

$$P(G) \leq c \cdot p_0, \quad (2.15)$$

:

$$G(n, p_{i,j}), \quad (2.16)$$

, . n c ,

,

:

$$P_{n,p}(G) = 1 - \frac{1}{n}$$

,

.

, . ,
 .
 , .
 .
 , .
 () (),
 .
 , , ,
 ,
 :
 - ;
 - , .
 :
 - , ;
 - , ();
 - ,
 (-).

3

D2D

, device, , ,
 (,) p.
 D2D, , . ,
 , device
 , (device:
 3.1). device

$$\rho = \frac{n}{s} (/ .), \tag{3.1}$$

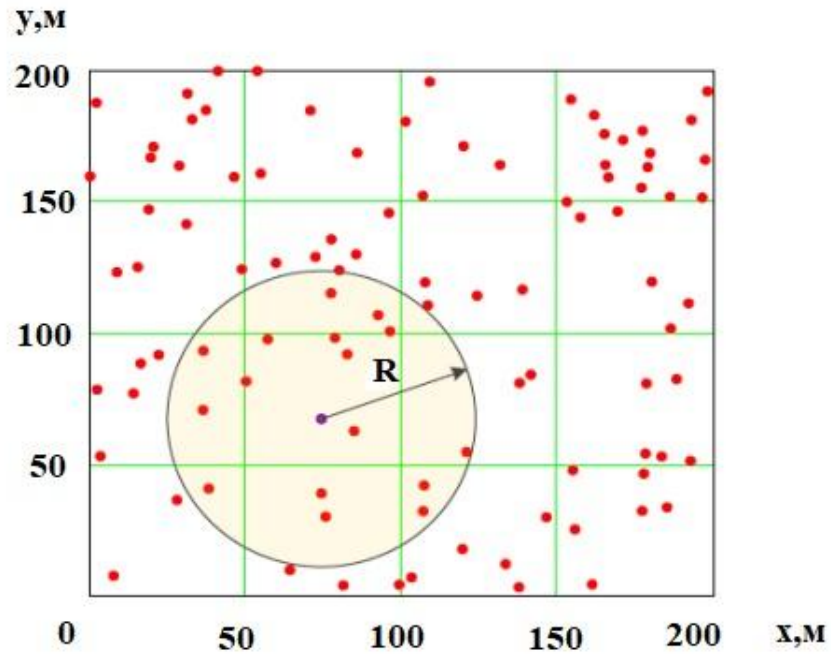
, , device
 R, , device
 :

$$p_R = \frac{k(R)}{n}, \tag{3.2}$$

n – device ;
 k(R) – device,
 device, device,
 , :

$$k(R) = \rho s_R = \rho \pi R^2, \tag{3.3}$$

$$s_R = \pi R^2 () - R.$$



3.1 – devices

, device

device

(device – B)

p_{ij}

$i \quad j.$

(,)

$$p_0 = \frac{\ln(n)}{n}, \tag{3.4}$$

n – device

, $p \quad e^{-1}, \quad p$

$$\frac{\ln(n)}{n} \cdot p \approx e^{-1}, \quad p_{R} > \frac{\ln(n)}{n}.$$

$$p < \frac{\ln(n)}{n},$$

$$p > \frac{\ln(n)}{n} -$$

p device

device.

$$k = \rho \cdot s, \tag{3.5}$$

ρ – device ;

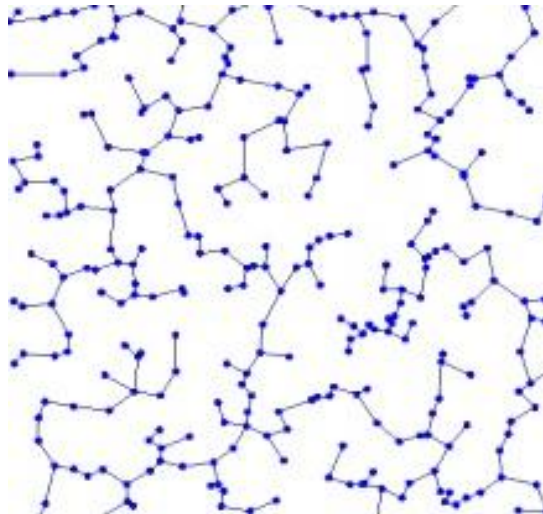
s – , device .

3.2 3.3

, 300 ,

, device, $R_1 = 60$ (3.1) $R_2 = 25$ (3.2).

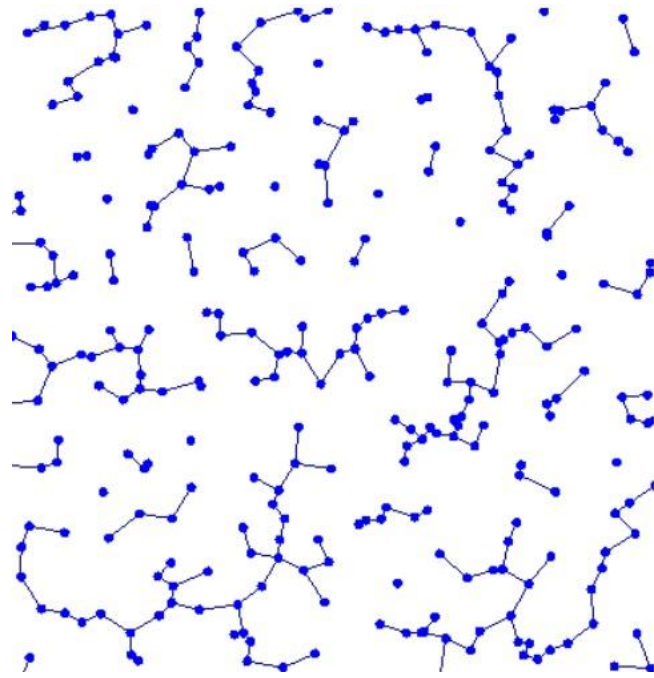
C#.



3.2 –

300

$R_1 = 60$



3.3 –

300

$$R_2 = 25$$

, 25

« » ()

· , ,

, , device A B

·

, -

, - .

,

:

- ;

- ;

- .

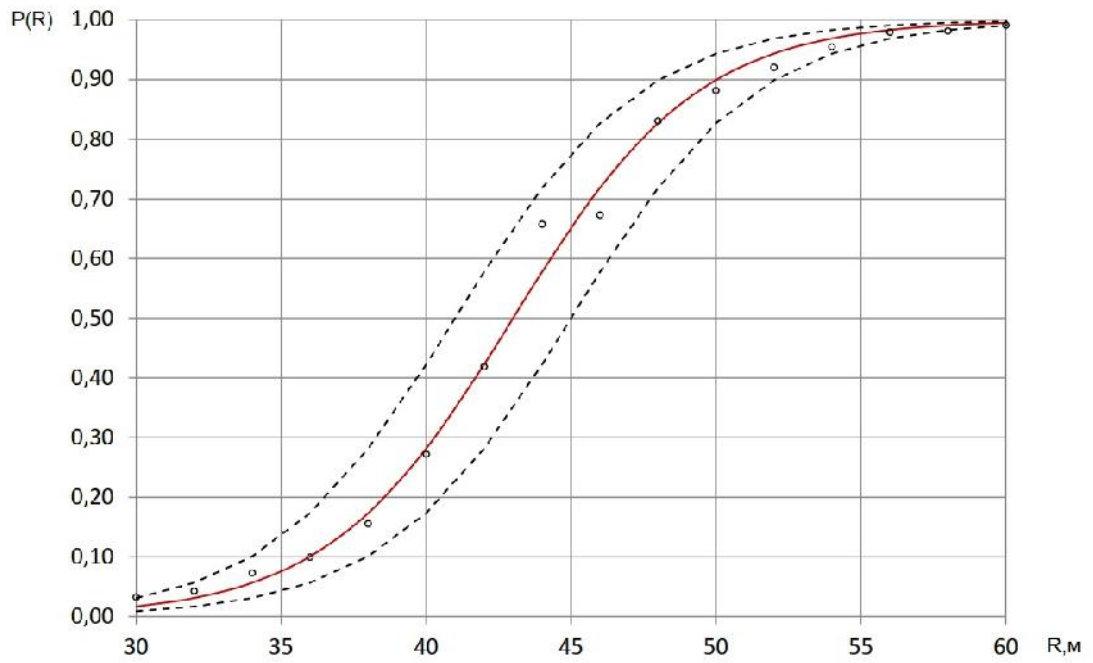
device

device

3.4

300

200x200



3.4 –

P_R

(0,95),

().

D2D

device,

,

,

.

D2D

’ . , ’ devices

D2D , D2D,

’ , devices, ’ D2D.

’ D2D.

’ D2D.

1.
BIG DATA « -
 »/ //
 , ' . - 2017. 2(42). - .154-157
2.
 « - »
BIG DATA /
 // , ' . - 2017. 4(44). - .102-105.
3. . 118921 , H04W 64/00.
 / - u201704085;
 . 24.04.2017; . 28.08.2017. . 16. 5 .
4.
 / //
 : V - . - , 13 - 15 . 2017 . -
 , 2017. - .36.
5.
 /
 //
 : (-2017), **XVII**
 - , 30 . 2017 . - ,
 2017. - .205 - 210.
6. -
 : (.)

