Detection and analysis of paedophile activity in P2P networks

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Context

Large sets of queries

- Interaction between users and search engines
- Applications
  - Traditional (system improvements)
  - Original (Google Flu)

Paedophile activity in P2P systems

- Children victimization
- Danger for innocent users
- Societal problem

Very little is known

Goals

Increase knowledge
of paedophile activity in P2P systems

Detection

- Create an automatic tagging tool
- Elaborate a generic methodology

Analysis

- Rigorous quantification of queries
- Study users

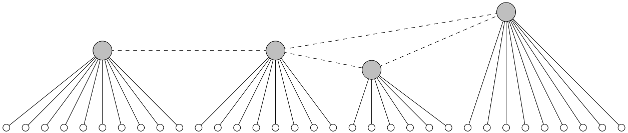
General methodology
Rare topic

Challenges

- Appropriate data collection
  size, dynamics, poorly documented protocols
- Automatic detection tool
  hidden activity, several languages
- Rigorous statistical inference
  low amount of paedophile queries
- User identification
  partial information, unreliable

Datasets

- Queries submitted to eDonkey search engine



2007 10 weeks, 100 millions queries, 24 million IP addresses

2009 147 weeks, 1,3 billion queries, 82 million IP addresses

- Set of queries : $q_i = (t, u, k_1, k_2, \ldots, k_n)$
  - t timestamp
  - u user information (IP address, connection port)
  - $(k_1, k_2, \ldots, k_n)$ sequence of keywords

Duly anonymised

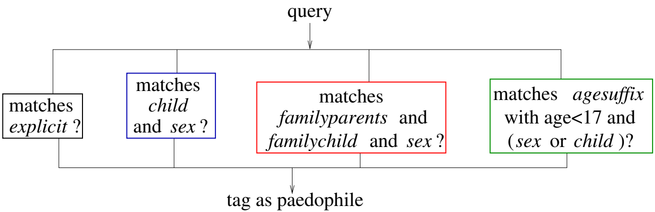
Outline

1. Paedophile queries
   - Tool design
   - Tool assessment
   - Fraction of paedophile queries
2. Paedophile users
3. Temporal dynamics
4. Conclusion

Tool design

- Set of rules based on law-enforcement knowledge
- Manual inspection of our datasets
- Improve until negligible changes

- 4 categories of paedophile queries



query

matches *explicit* ?

matches *child* and *sex* ?

matches *familyparents* and *familychild* and *sex* ?

matches *agesuffix* with age<17 and (*sex* or *child*)?

tag as paedophile

raygold little girl porno infantil incest mom son video 12yo fuck video

Quality

False positive

"sexy daddy destinys child"
contains "sexy", "daddy" and "child"
but most likely a music-related query

False negative

"pjk 12yo"
contains paedophile keywords that we don't search for

How to estimate false positive and false negative rates?

Tool assessment – Survey

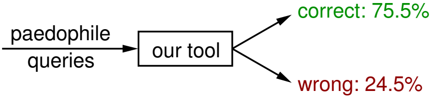
- Set of 21 volunteering experts (Europol, national authorities, NGOs)
- Set of 3,000 randomly selected queries:
  - Paedophile
  - Not paedophile
  - *Neighbours* (submitted within the 2 previous or next hours of a paedophile query by the same user)
- Tag queries as *paedophile*, *probably paedophile*, *probably not paedophile*, *not paedophile* or *I don't know*

Tool assessment – Survey results

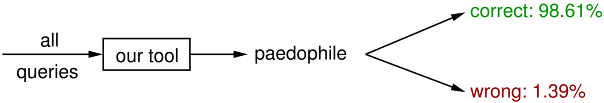
	prob.	*don't*	*prob.*	*not*		
paedo	*paedo*	*know*	*not*	*paedo*	total	relevance
1530	149	25	66	1230	3000	99.5
1381	247	125	580	667	3000	98.5
1679	89	2	113	1117	3000	99.1
1603	201	99	174	923	3000	99.0
1598	5	15	1	1381	3000	98.8
128	81	1	26	124	360	100.0
216	154	0	142	132	644	98.4
1624	126	16	165	581	2512	99.8
351	16	2	16	27	412	100.0
647	119	71	40	439	1316	98.4
1174	111	20	64	789	2158	99.1
335	17	1	70	166	589	97.5
641	383	4	112	753	1893	97.8
1071	546	2	453	928	3000	88.4
1554	197	28	327	894	3000	97.6
1506	120	6	25	393	2050	98.3
305	270	24	89	181	869	99.0
371	1017	496	570	546	3000	95.7
976	936	405	594	89	3000	96.6
344	12	10	70	156	592	98.3
845	139	323	175	182	1664	97.9

- Relevance rate: adequate knowledge of specific context

Assessment results



paedophile queries → our tool → correct: 75.5% / wrong: 24.5%



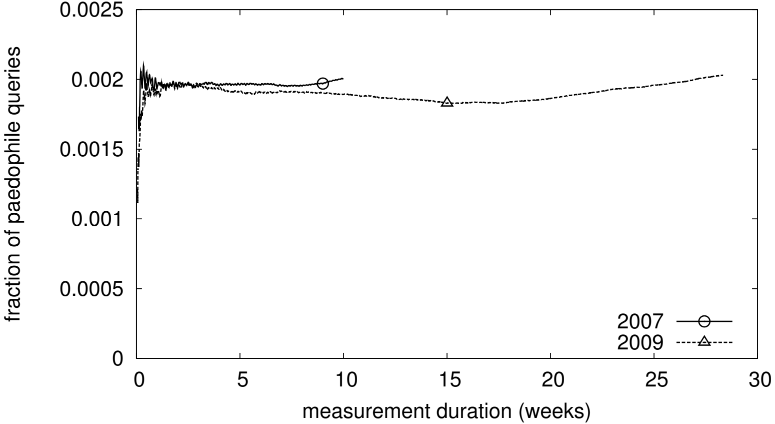
all queries → our tool → paedophile → correct: 98.61% / wrong: 1.39%

Assessment results

$$\frac{|P^+|}{|D|} = \frac{(1 - f'^+)}{1 - f^-} \frac{|T^+|}{|D|}$$

- P^+ : paedophile queries
- T^+ : tagged paedophile queries
- f'^+ : false positive rate
- f^- : false negative rate

Fraction of detected paedophile queries



Fraction of paedophile queries

Result

- Detected queries: slighlty above 0.19% for both datasets
- After correction: 2,5 queries out of 1,000 are paedophiles
- 1 paedophile query every 33 seconds

📄 MATTHIEU LATAPY, CLÉMENCE MAGNIEN, AND RAPHAËL FOURNIER. Quantifying paedophile queries in a large P2P system. In *IEEE International Conference on Computer Communications (INFOCOM) Mini-Conference*, 2011.

📄 MATTHIEU LATAPY, CLÉMENCE MAGNIEN, AND RAPHAËL FOURNIER. Quantifying paedophile activity in a large P2P system. *Information Processing and Management*, In press, 2012.

Outline

1. Paedophile queries
2. Paedophile users
   - Distinguishing different users
   - Fraction of paedophile users
3. Temporal dynamics
4. Conclusion

Distinguishing users

Possible approximation:
user $\sim$ IP address

Problems

- Gateway/firewall (NAT) IP addresses
- Dynamic addresses allocation
- Several users per computer
- Several computers per user

Distinguishing users

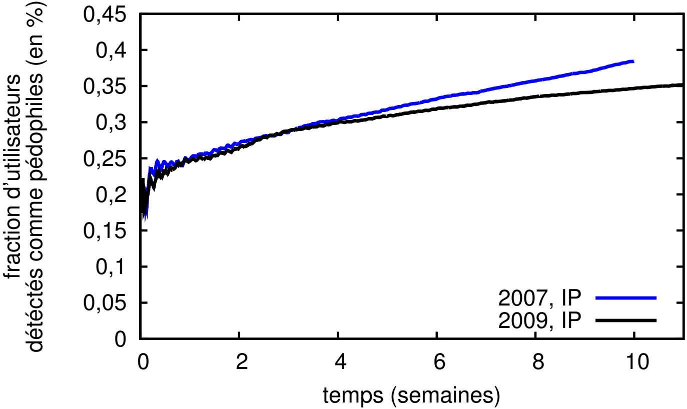
Paedophile user

- User paedophile after one paedophile query
- All dynamic/public IP addresses may be considered as paedophile *after some time*

3 approches :

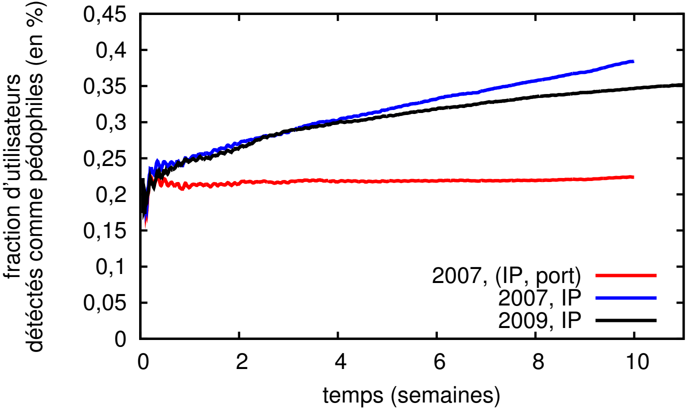
- User $\sim$ IP adress + connection port
- Measurement duration
- Sessions

User: IP *vs* (IP,port)



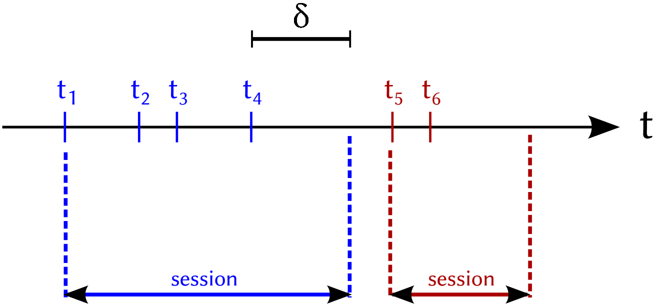
- (IP, port) reduces pollution (bias)

User: IP *vs* (IP,port)

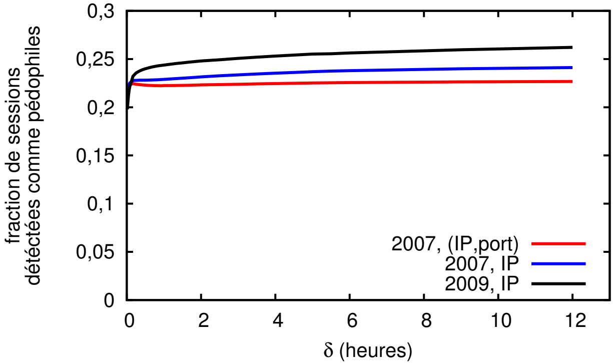


- (IP, port) reduces pollution (bias)

User: sessions



User: sessions



Fraction of paedophile users

- False positive/negative rate on users
  - $p(u \in U^+ \mid u \in V(n, 0)) = 1 - (1 - f'^-)^n$
  - $p(u \in U^- \mid u \in V(n, k)) = (f'^+)^k (1 - f'^-)^{n-k}$

  - U$^+$, U$^-$: set of paedophile/not paedophile users
  - V$^+$, V$^-$: set of users detected as paedophile/not paedophile
  - n : number of queries of a user
  - k : number of queries detected as paedophile for a user
- $\frac{|U^+ \cap V^+|}{|D|} = \sum_{n=1}^{N} \sum_{k=1}^{n} (1 - (f'^+)^k (1 - f'^-)^{n-k}) \frac{|V(n,k)|}{|D|}$

Fraction of paedophile users

Result

- Fraction of paedophile users close to 0,22% for both datasets
- 1 paedophile user out of 450

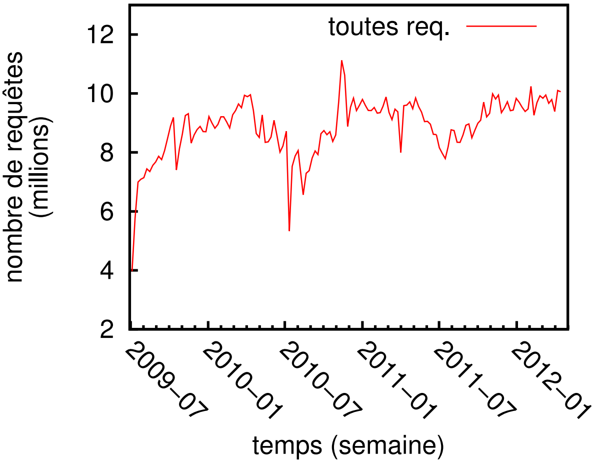
Matthieu Latapy, Clémence Magnien, and Raphaël Fournier. Quantifying paedophile queries in a large P2P system. In *IEEE International Conference on Computer Communications (INFOCOM) Mini-Conference*, 2011.

Matthieu Latapy, Clémence Magnien, and Raphaël Fournier. Quantifying paedophile activity in a large P2P system. *Information Processing and Management*, In press, 2012.

Outline

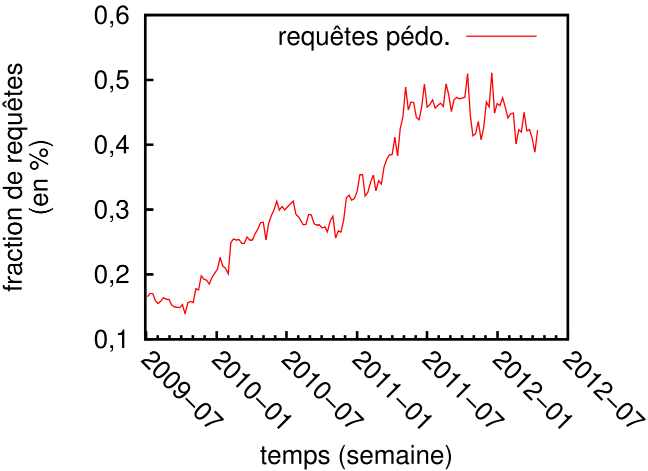
1. Paedophile queries
2. Paedophile users
3. Temporal dynamics
   - Long-term evolution of paedophile activity
   - Daily evolution of paedophile activity
4. Conclusion

Global traffic on server



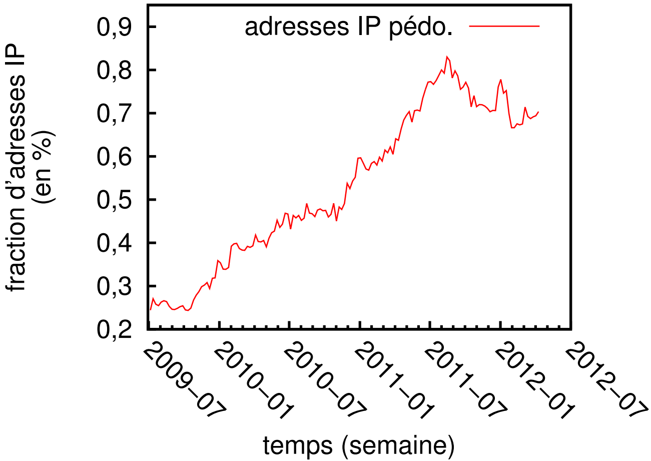
- Stability of global traffic over 3 years

Fraction of paedophile queries



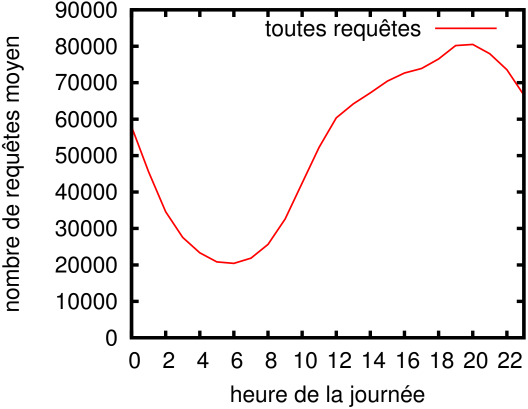
- Fraction of paedophile queries strongly increasing

Fraction of paedophile users



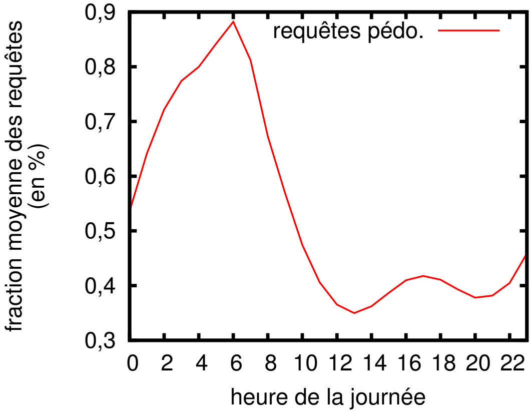
- Fraction of paedophile users also increasing

Daily traffic



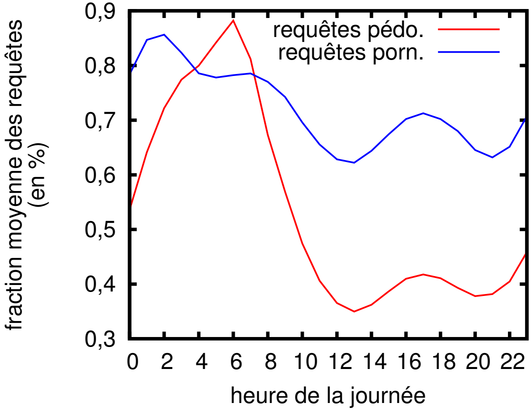
- Circadian cycle (day/night effect)

Fraction of paedophile activity



- Fraction of paedophile queries peaks at 6 AM

Pornography vs paedophile activity



- Paedopornagraphy and traditional pornography differ

Évolution de l’activité

Résultat

- Important growth of paedophile activity between 2009 and 2012
- Fraction of paedophile queries peaks at 6 AM
- Qualitative contribution with quantitative approach

Outline

1 Paedophile queries

2 Paedophile users

3 Temporal dynamics

4 Conclusion

Conclusion (1/2)

1. Paedophile queries

   automatic detection tool
   set of paedophile queries
   estimated fraction of paedophile queries

2. Paedophile users

   general study of user identification
   quantification of paedophile users

Conclusion (2/2)

3. Temporal dynamics

three-year study
user social integration

4. Comparing KAD and eDonkey

adequate methodology
analysis with partial information

R. Fournier, T. Cholez, M. Latapy, C. Magnien, I. Chrisment, I. Daniloff and O. Festor.
Comparing paedophile activity in different P2P systems. Submitted.

Perspectives

Tool improvement

- previous/next queries
- languages, word order, categories
- machine learning

Analysis

- different thresholds for paedophile users
- community detection (graph topology)
- detailed study of sequences of queries
- file exchanges (supply)

- Apply methodology to other contexts

Contact

Thank you for your attention.

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KAD network

- Completely distributed protocol of clients
- No server for file indexing
- Some peers are in charge of some files and keywords

Principle:

- Precise and targeted injection of peers into the network to control files or keywords
- Peers catch queries and control replies

Applications:

- Which files are published for a given keyword? Which peers share them ?
- Eclipse : prevent peers from accessing content

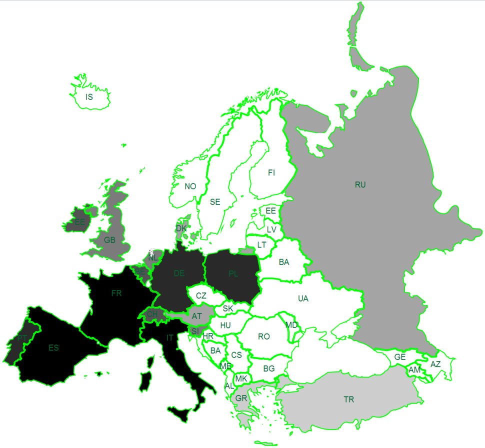
Geo-location: statistics

country	# queries	# paedo	ratio
IT	19569361	15426	0.08 %
ES	8881405	5177	0.06 %
FR	7583815	8059	0.11 %
BR	2795090	4849	0.17 %
IL	2139697	2618	0.12 %
DE	2093106	11238	0.54 %
KR	1386799	336	0.02 %
US	1053183	6184	0.59 %
PL	975170	1178	0.12 %
AR	810466	1465	0.18 %
CN	635392	337	0.05 %
PT	513327	434	0.08 %
IE	511185	54	0.01 %
TW	417893	138	0.03 %
BE	402565	646	0.16 %
CH	320054	1710	0.53 %
GB	319386	1698	0.53 %
NL	243646	1131	0.46 %
CA	241460	1233	0.51 %
SI	239572	167	0.07 %
MX	210504	1098	0.52 %
RU	200958	2712	1.35 %
AT	184248	977	0.53 %

Biased by:

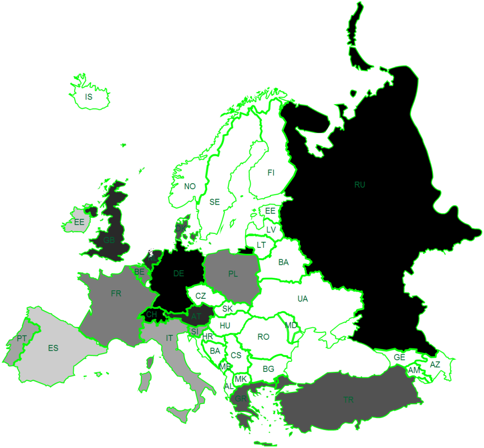
- language knowledge
- decoding problems

Geo-location: maps



# queries

Geo-location: maps



ratio # paedophile queries / # queries