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Handling Network Security Issues Using AI

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Abstract: With excessive exposure and use of internet, every system is prone to wide range of attacks. With this perspective, Network security is gathering every ones' concern. Network attackers are getting more and more innovative with designs. Exponential growth in attacker's intelligence require mitigation mechanism to be updated with same speed and level of innovation. This pans avenues for advanced technologies and methods to be employed for handling network security issues. Trending ones are artificial intelligence(AI), machine learning (ML) and deep learning(DL). AI is an umbrella covering ML and DL under it. Main features of AI making it big deal for network security are capacity to handle big data, faster detection, quick response, ability of unsupervised processing. Considering mentioned aspects, comprehensive study of AI approaches in handling network security issues is been carried out.
Keywords: network security,machine learning(ML), deep learning(DL), recommender systems, artificial intelligence(AI)

I. INTRODUCTION

Artificial Intelligence, as the name suggests, is a induced form of intelligence in any kind of entity which naturally does not possess such kind of intelligence. By inducing certain kind of intelligence the entity can act as a matter expert. This is exact concept behind use of AI, finding solution to something, as if found by subject expert. Another main feature of AI to be so popularly employable is speed with which it can analyze data. Expert will take much longer to analyze big data, but with use of AI, it will be a matter of fraction of second. Thus complex situation solution finding is done by this science stream, and as it can take decisions also, like humans, the stream is know as Artificial Intelligence. Algorithms try to model decision making power as in humans. Decision making power is possessed by brain in humans, but creating human brain like structure was found to be way too complex, so modeling decision power mechanism was concentrated upon by AI field masters. So now with availability of suitable data, maximum complex problems can be solved using AI. Using various softwares algorithms are implemented to create AI applications possessing decision making power similar to that of human expert. Such AI applications can be used in absence of experts or in places where experts are not available. AI applications can be employed to take decisions from available data. Such applications need to be trained first, using past data. Using statistical methods available data can be used to generate information. Generated information is employed for prediction or decision making. Above specified flow will be implemented by a sub domain of AI, known as Machine Learning(ML). Deep Learning(DL) will also be useful for the same. Consider case of cancer specialist doctor. Decision on cancer cells are made by him considering size, growth rate, mutation rate, enzymes secreted etc. if such data with cancer features present are used to train AI application using ML, then AI application can be used in Hospitals, in absence of cancer specialist doctor, to make decisions. Thus for every problem, to have it solved by AI application, related dataset with feature set is required.

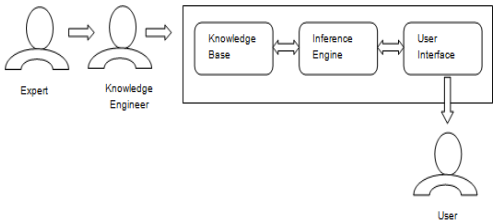


Fig. 1 AI application top view

TABLE I. Advantages & Disadvantages of AI Concepts

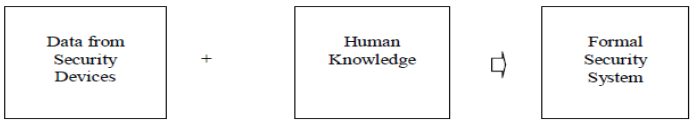
AI Concept	Advantages	Disadvantages
Data Mining	• Can handle tons of data • Finds required useful data from piles of it. • Great for decision making	• Privacy of user compromised • Personal data can be misused
Expert System	• Works 24X7 • Consistency of output maintained in case of repetitive tasks	• Knowledge base dependency • A small error in knowledge base propagates higher
Fuzzy Logic	• Robust algos with less memory requirements	• Insensitive to environmental changes
Image Processing	• Useful when processing without human interference is required • Less expensive	• Initial/set-up budget is higher • Optimum Input is expected
Neural Network	• Ease of use with robustness and complex function modeling power • Adaptability to changing environment and high speed	• Initial/set-up budget is higher • Optimum Input is expected
Pattern Recognition	• Automatic, quick and faster pattern recognition • Accurate pattern classification	• Output is completely dependent on authenticity of input
Machine Learning	• Automated processing without human interference is achieved	• Output is completely dependent on training set
Deep Learning	• Unsupervised -faster processing	• Model training complexity

Advantages of Artificial Intelligence for network security

TABLE II. Advantages of AI for network security

Continuous up gradation of AI application's Efficiency and Intelligence.	Humans take more time for learning and up gradation, but smartness can be induced in AI applications faster. Process is continuous, unlike humans who get tired and need breaks
No downtime for AI application	AI application being non living will be up without any sort of breaks
Quicker detection of threats	Machine learning trained model has greater detection speed as compared with humans, Faster AI algorithm use will generate more quicker responses by application
System immunity scaling	In case multiple types of devices, like stationary & mobile, are used for data transfer then all devices must be capable of possessing same level of resistance

- **Formal Security System-**



- **Security System based on Artificial Intelligence-**

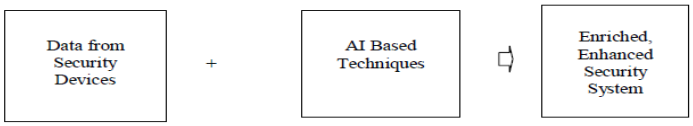


Fig. 2 Security system with AI[6]

II. RECENT ADVANCES IN AI FIELD

A. Machine Learning and Network Field

In 1959, Arthur Samuel coined the term "Machine Learning", as "the field of study that gives computers the ability to learn without being explicitly programmed" [369]. Ability is gained by use of concepts, mainly, clustering, classification, regression and rule extraction. Different learning approaches supported are-supervised, unsupervised, semi-supervised and reinforcement learning.

TABLE III. ML Learning Approaches

Learning approaches supported by ML	Supervised	Large labeled training datasets	Classification And regression problems	Malware Identification, Spam Detection, Denial-of-Service (DoS), User-to-Root (U2R), Root-to-Local (R2L), or probing, to predict of when a future failure will transpire
	Unsupervised	unlabeled training datasets	Clustering problems	Entity classification, Anomaly detection, Data exploration (density estimation problems in networking)
			Association rule learning	Entity classification, Anomaly detection, Data exploration
			Dimensionality reduction	
	Semi-Supervised	incomplete labels for training data or missing		Anomaly detection, Risk scoring

		labels		
	Reinforcement Learning	agent-based iterative process, training data in RL constitutes a set of state-action pairs and rewards (or penalties)	Decision making problems	--

ML Model Building

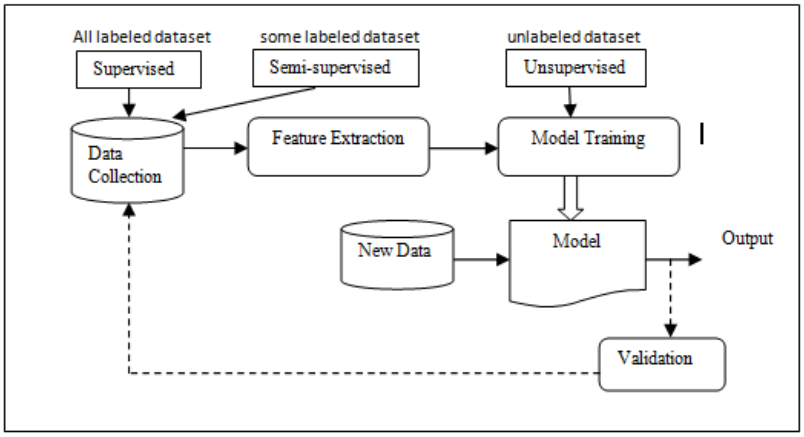


Fig. 3 Training A Model using Machine Learning

Training ML model
Training process is conducted in 3 main phases:
Phase I: Collecting data- This can be implemented in two ways, supervised or semi-supervised. Type of collection will be real time data collection and historical data collection. Historical data, being huge in amount, is a data where from model will learn. It can also act as test dataset. It is readily available with many repositories. Real time data will be input as well as feedback for model. This phase ends by dividing collected data into 3 types of subdivisions. One for train model, known as training set. One for performing validation, also known as development set and other one for testing model, known as test dataset. Training set is employed to shortlist ideal model parameters. Validation (development set) is employed to shortlist suitable ML model type. Lastly test dataset is employed to verify shortlisted model performance. Use of validation dataset is optional, as suitable ML model can be decided beforehand.

Phase II: Extracting features- before proceeding with extracting features, preprocessing of data collection is been done to clean data. Extracting features will shortlist features for training model with respect to them. This saves memory and time required for processing as collected data is huge in amount with some repetitive and some irrelevant features not contributing to result. Related to networking, features extracted can be of packet or flow or connection levels. Either use off the shelf tools (WEKA, NetMate etc.) or employ methods specialized in filter, embedding or wrapper.

Phase III: Training model- selected learning algorithm is given training dataset to learn from. Target attributes must be achieved by model during training phase. Those attributes refer to expected answer. Patterns of input relating to particular outputs are found by Learning algorithms. So when test/validate dataset is given to model, it will map new input to expected output using patterns found.

TABLE IV. ML Model Building Phases

Phase I	Collecting data	Supervised, Semi-supervised	Real-time data collection, Historical data collection	Training set, Validation set, Testing set (60/20/20)% of total dataset	Holdout , k-fold cross-validation		
Phase II	Processing features	Preprocessing step is used to clean data	Features with maximum relevant information are selected to train model on	Features represent statistical information about attribute of data.	Packet-level, flow-level, connection- level	Features selection and extraction tools – WEKA, NetMate	Feature selection and extraction methods- filter, embedded, and wrapper based methods
Phase III	Training model	Learning algorithm is selected	Training dataset acts as input	Patterns relating input-output are found			
	Validation of data						

Types Of ML Models

ML models are classified as per the base algorithm used to develop model. Classification can be viewed as follows:

TABLE V. ML Model Examples[5]

Algorithm	**Model Name**	**Algorithm**	**Model Name**
Regression Algorithms	• Ordinary Least Squares Regression (OLSR) • Locally Estimated Scatterplot Smoothing (LOESS) • Logistic Regression • Stepwise Regression • Multivariate Adaptive Regression Splines (MARS) • Linear Regression	Association Rule Learning Algorithms	• Eclat algorithm • Apriori algorithm
Instance-based Algorithms	• k-Nearest Neighbour (kNN) • Locally Weighted Learning (LWL) • Learning Vector Quantization (LVQ) • Self-Organizing Map (SOM)	Artificial Neural Network Algorithms	• Perceptron • Hopfield Network • Radial Basis Function Network (RBFN) • Back-Propagation
Regularization Algorithms	• Ridge Regression • Least-Angle Regression (LARS) • Least Absolute Shrinkage and Selection Operator (LASSO) • Elastic Net	Deep Learning Algorithms	• Deep Boltzmann Machine (DBM) • Stacked Auto-Encoders • Deep Belief Networks (DBN) • Convolutional Neural Network (CNN)
Decision	• Classification and	Dimensionali	• Linear Discriminant

Tree Algorithms	Regression Tree (CART) • Iterative Dichotomiser 3 (ID3) • Decision Stump • M5 • C4.5 and C5.0 (different versions of a powerful approach) • Chi-squared Automatic Interaction Detection (CHAID) • Conditional Decision Trees	ty Reduction Algorithms	Analysis (LDA) • Mixture Discriminant Analysis (MDA) • Principal Component Analysis (PCA) • Sammon Mapping • Quadratic Discriminant Analysis (QDA) • Flexible Discriminant Analysis (FDA) • Multidimensional Scaling (MDS) • Projection Pursuit • Principal Component Regression (PCR) • Partial Least Squares Regression (PLSR)
Bayesian Algorithms	• Naive Bayes • Gaussian Naive Bayes • Bayesian Belief Network (BBN) • Bayesian Network (BN) • Multinomial Naive Bayes • Averaged One-Dependence Estimators (AODE)	Ensemble Algorithms	• Gradient Boosted Regression Trees (GBRT) • Random Forest • Boosting • Stacked Generalization (blending) • Gradient Boosting Machines (GBM) • Bootstrapped Aggregation (Bagging) • AdaBoost
Clustering Algorithms	• k-Means • Hierarchical Clustering • k-Medians • Expectation Maximisation (EM)	Other Algorithms	• Reinforcement Learning • Graphical Models • Computational intelligence (evolutionary algorithms, etc.) • Recommender Systems • Computer Vision (CV) • Natural Language Processing (NLP)

TABLE VI. ML Model Classification

Broader and more generalized classification can be viewed as, based on type of output, follows:			
Binary Classification Model	Outputs one out of two classes	Binary Classification Examples • Spam/non-spam email detection • Product will be bought?	
Multiclass Classification Model	Outputs one out of more possible classes	Multiclass Classification Examples • Product category detection	
Regression Model	Outputs a numeric value	Regression Examples • Temperature prediction	
Broader and more generalized classification can be viewed as, based on type of input, follows:			
Logical Expression	Tree models Rule models.		
Probability	Naïve Bayes		
Geometric Expression	Linear models Distance-based models		

B. Deep Learning and Network Field

Deep learning is sub field of ML, which in turn is a sub domain of AI. "Deep" here indicates multiple/deep layers of neural nets. This concept increases scalability of artificial neural nets. It helps to model and learn complex concept by building it using low-medium-high level feature extraction. Thus layers of neural nets get multiple &/or deeper. Neural Nets with lesser layers are known to use shallow learning.

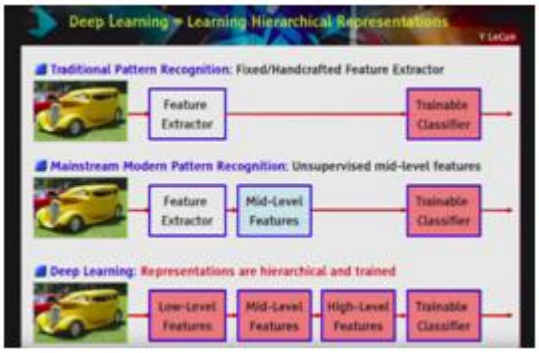


Fig. 4 Deep Learning Concept[4]

https://machinelearningmastery.com/what-is-deep-learning/

Deep Learning Methods Used in Cyber Security

TABLE VII. Deep Learning Methods[1]

Deep Belief Networks	**Recurrent neural network (RNN)**	**Convolutional Neural Networks**	**Generative Adversarial Networks**	**Recursive Neural Networks**
- class of DNNs composed of multiple layers of hidden units with connections between the layers but not between units within each layer - DBNs are trained in an unsupervised manner - trained by adjusting weights in each hidden layer individually to reconstruct the inputs	-Takes variable Lengths input sequences - one element a time inputs processing - output of the hidden unit acts as extra input - addresses speech problems, time series problems along with language problems -more difficult to train because the gradients can easily vanish or explode -holds a memory of the past events in the sequence	-processes input stored in arrays. -Regardless of dimensionality, CNNs are used where there is spatial or temporal ordering -consists of three distinct types of layers -convolution layers, pooling layers, and the classification layer -convolution layers are the core of the CNN. -weights define a convolution kernel applied to the original input	- two neural networks compete against each other -one network acts as a generator and another network acts as a discriminator -minator. generator -on reading input ,generates outputs data with real data characteristics -discriminator reads real data long with generator output to judge input is real or fake. -thus generator can now generate new data similar to real data. -uses are image enhancement, caption generation, optical flow estimation	- apply set of weights recursively to a series of inputs. - output of a node is used as input for the next step - first two inputs are fed into the model together - output from that is used as an input along with the next step -uses natural language processing tasks, image segmentation

TABLE VIII. DBN Sub-Types[1]

DBN Sub Types→	**Deep Autoencoders**	**Restricted Boltzmann Machines**	**DBNs or RBMs**
Model type	Unsupervised neural networks	Two-layer, bipartite, undirected graphical models	Deep autoencoders coupled with classification layers
Class of neural networks	Unsupervised	Unsupervised	Unsupervised
Input is	Vector	Data	Data
Training way	one layer at a time	one layer at a time	trained using back propagation, layers require labels to train
Uses	feature compression (encoding), denoising input, stacked autoencoder, sparse autoencoder	Stacked RBMs	Feature extractor, acoustic modeling, speech recognition, image recognition

Activation function

TABLE IX. Details of Activation Functions[2]

Activation Functions	**Method**	**Advantages**	**Disadvantages**
Binary Step	Threshold based step function	Simplicity of design	Works only with two classes, zero gradient makes it useless for back-propagation
Linear Function	Linear function	Ideal for simple tasks	Not suitable for complicated task
Sigmoid	f(x)=1/(1+e^-x)	Very high gradient for small interval, non-linear output , Back-propagation suitability	Asymmetric around origin, gradient small for region other than -3 to 3
Tanh	scaled version of the sigmoid function tanh(x)=2sigmoid(2x)-1	Symmetric around origin, Back propagates errors, Better version of sigmoid	Gradient vanishes after certain interval
Rectified linear unit (ReLU)	f(x)=max(0,x)	Non linear output, Back propagates errors, Selected neurons activation makes network sparse increasing ease and efficiency of computation.	Gradients approaching zero problem, Back propagation without updating weights
Leaky ReLU	f(x)=ax, x<0 =x, x≥0	No zero gradient	Dead neurons problem unsolved
Softmax	$\sigma(\mathbf{z})_j = \frac{e^{z_j}}{\sum_{k=1}^{K} e^{z_k}}$ for $j = 1, \ldots, K$.	Handles multiple classes	

Deep learning applications

TABLE X. Deep Learning Applications

Virtual assistants	Deep learning makes understanding and comprehending human language easy for machines while interacting
Translations	Helps in language translation
Vision for driverless delivery trucks, drones and autonomous cars	More input data gives more vision to devices.
Chat &/or service bots	Provide customer services in human absence
Image colorization	Black-white image recreation to colored one
Facial recognition	Used for security as well as on social media platforms to tag people
Medicine and pharmaceuticals	Disease diagnosis & customized medicine formation
Personalized shopping and entertainment	User preference driven suggestions

TABLE XI. Cyber Security Using Deep and Shallow Learning[3]

		Intrusion Detection			Malware Analysis	Spam Detection
		Network	Botnet	DGA		
Deep Learning	Supervised	RNN [8]	RNN [9]		FNN [10] CNN [11] RNN [12]	
	Unsupervised	DBN [13] SAE [14]			DBN [15] SAE [16]	DBN [17] SAE [18]
Shallow Learning	Supervised	RF [3] NB [3] SVM [3] LR [3] HMM [3] KNN [3] SNN [3]	RF [19] NB [19] SVM [19] LR [20] KNN [21] SNN [22]	RF [23] HMM [23]	RF [24] NB [24] SVM [24] LR [24] HMM [25] KNN [24] SNN [26]	RF [27] NB [28] SVM [28] LR [27] KNN [27] SNN [27]
	Unsupervised	Clustering [29] Association [30]	Clustering [5]	Clustering [31]	Clustering [24] Association [32]	Clustering [33] Association [34]

III. FUTURE TRENDS

Recommender Systems and Network Field

Recommender systems are playing the pivotal role in influencing users and thereby helping e-commerce business by turning users into potential buyers or customers. The users are happy with the recommender system functionality as they are getting suggestions at their feet, derived from existing customers' experiences and trends of buying. This is very much a need of an hour as we have entered the era of big data. Same is the scenario with network traffic, which is increasing with tremendous speed every second. With the amount of traffic data, vulnerability to threats is also on rise. So if such huge amount of past network traffic data can be analyzed and used with recommender system, then the predictions can be obtained regarding the anomalous situations to be encountered in future and suggestions can be provided immediately for mitigation actions.

As the amount of available data grows, the problem of extracting useful information becomes more difficult, which can lead to information overload. Recommender systems play a major role in such situations as they minimize costs of searching and choosing products in an e-commerce environment[9]. Recommender systems have also proved to improve decision making process and quality [10]. These features of recommender systems can be employed for network security domain. The huge amount of past network traffic data will be analyzed and profiling of each node in communication will be done. Using network traffic prediction methods and similarity index check, the anomalous situations will be notified for which recommender system will suggest mitigation actions. As the job of network security analyst is been automated, MTTR will definitely be reduced, which further will be enhanced by mitigation action suggestions. In this regards researchers tried to collaborate with different recommender techniques considering the nature of domain data and requirements. Here summary of study related to some important recommender techniques and survey of employability of recommender system in network security domain is presented.

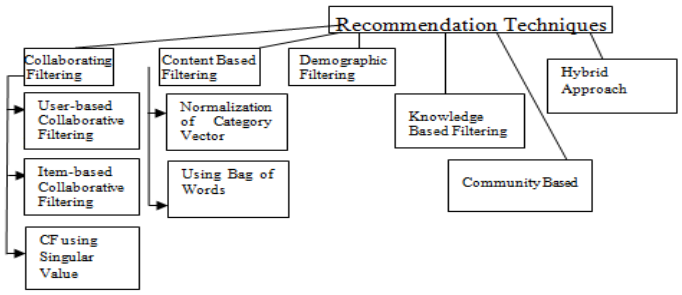


Fig.5 Recommendation Techniques

TABLE XII. Summary of recommendation techniques[11]

Recommendation Technique	Process	Advantages	Disadvantages
Collaborative Filtering	Finding users in U similar to u regarding their choices. So preferences of other users are used with maximum similarity index. Word-of-mouth concept is employed.	Implicit feedback sufficient, domain knowledge not required. Can be used for cross-genre, quality improves over the time.	cold start, scalability, and sparsity, insensitive to performance changes, quality depends on large historic dataset
Content Based Filtering	Recommends items matching in contents with user profile. Each item must have content descriptor in form of words description in document.	No need of other users data, capable of recommending new & unrated item, transparency in recommendation process (results can be justified)	User are been suggested with items already rated which makes recommendations obvious, no unexpectedness in results, It is difficult to recommend if there is a limited content about the user profile Do not consider inter-dependencies or complex behavior.
Demographic	Demographic Recommender system generates recommendations based on the user demographic attributes.	It is easy to implement and does not require user ratings.	The items not matching with demographic attributes will never be recommended.
Knowledge Based filtering	The cases where above mentioned filtering techniques can not be used, knowledge based filtering is employed.	no cold-start problems. Suitable for complex domain with less item transactions.	Knowledge acquisition must be done often. Explicit definition of recommendation knowledge is must.
Community Based filtering	Groups of users-items with highly matching interests are formed.	As groups are formed, group behavior pattern understanding is easy. .	Some user's suggestions may get generalized.
Hybrid Approach for filtering	Combines above mentioned approaches as per requirements.	Combines advantages of approaches merged & overcomes disadvantages of approaches merged	--

TABLE XIII. Survey of recommender systems in various domains

PAPER	TECHNIQUE USED	FIELD OF APPLICATION	USE
Using Collaborative Filtering in a new domain: traffic analysis CERI '16, June 14 - 16, 2016, Granada, Spain[14]	Collaborative Filtering	Computer Networks	To apply the collaborative filtering techniques to the field of troubleshooting and reducing threats in an IT infrastructure.
CCFRS – Community based Collaborative Filtering Recommender System Journal of Intelligent & Fuzzy Systems 32 (2017) 2987–2995[12]	Community based Collaborative Filtering	Digital Library (Books Domain)	To generating community based individual recommendations for the user.
A Community Based Social Recommender System for Individuals & Groups, SocialCom/PASSAT/BigData/EconCom/BioMedCom 2013[16]	Community Based	Social Network of Movies (Movie Domain)	Movies are recommended based on their community membership, the degree utility value, adjacent nodes, and star ranking.
A Recommender-System for Telecommunications Network Management Actions, at: https://www.researchgate.net/publication/259785776,2013[17]	Collaborative Filtering	Telecoms Network management system	The applicability of recommender systems as an approach toassist NOC operators to correctly respond to indications ofincidents in the network they are actively managing.
A Survey of Collaborative Filtering-Based Recommender Systems for Mobile Internet Applications, Digital Object Identifier 0.1109/ACCESS.2016.2573314, 2169-3536 2016 IEEE. [18]	Collaborative Filtering	Mobile Internet applications.	To predict the interests of mobile users and to make proper mobile application recommendations.
A Hybrid Trust-Based Recommender System for Online Communities of Practice IEEE TRANSACTIONS ON LEARNING TECHNOLOGIES, VOL. 8, NO. 4, OCTOBER-DECEMBER 2015[19]	Hybrid Approach	Online Community of Practices (Online forums to seek answers)	To mitigate two issues, when learners face information overload and there is no knowledge authority within the learning environment, in online CoPs.
User Profiling for University Recommender System using Automatic Information Retrieval	Collaborative Filtering	Education Domain (University/ Institute Online	User Profiling System for recommendation of various Universities/Institutions/Colleges by extracting, integrating and identifying

Procedia Computer Science 78 (2016) 5 – 12, International Conference on Information Security and Privacy, 11-12 December 2015, Nagpur, INDIA[20]		Information)	the keyword based information to generate a structured Profile and then visualizing the knowledge out of these findings.
ePaper - the Personalized Mobile Newspaper, Journal of the American Society for Information Science and Technology · November 2009 [21]	Collaborative Filtering	Digital News Domain	The ePaper aggregates content (i.e., news items) from various news providers, and delivers personalized newspapers on dedicated mobile, electronic newspaper-like, devices.
TiMers: Time-based Music Recommendation System based on Social Network Services Analysis, IMECS 2015, March 18 - 20, 2015, Hong Kong[22]	Hybrid Approach	Digital Music	Extracts the general and personal tastes of music by analyzing current music playback that are collected from the popular radio stations and social network services during a specific time period and generate a list of songs for recommendation by emotion and genre.

IV. DISCUSSION AND SUMMARY

The recommender system methodology is immensely popular among the e-commerce business. The benefited users are satisfied by the results as they no more have to trawl through piles of products available at their fingertips. Similarly as network traffic data is also growing every second, the recommender system can be employed for network security domain to suggest mitigation actions in case anomalous situation is been predicted by traffic prediction module. The network analyst no more has to scroll through logs of traffic traces for suspicious traffic. As the anomalous situation is predicted beforehand, MTTR(mean time to respond) will improve drastically. The various network traffic prediction methods are listed. The survey of various literatures shows use of recommender system in various domains other than e-commerce. Concepts of AI , specifically ML, DL and recommender systems, are thus front runners to handle various network security issues effectively and efficiently.

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